

BEGINNING TO FLY



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ARAM ABGARIAN SHOWING THE PROPER METHOD OF
LAUNCHING AN INDOOR ENDURANCE MODEL

Abgarian established a new world's record of 207 seconds with
this model

BEGINNING TO FLY

The Book of Model Airplanes

BY

MERRILL HAMBURG

WITH AN INTRODUCTION BY

COMMANDER RICHARD E. BYRD

With Illustrations and Diagrams

NEW EDITION, REVISED AND ENLARGED



BOSTON AND NEW YORK
HOUGHTON MIFFLIN COMPANY

The Riverside Press Cambridge

1930

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1930

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The Riverside Press
CAMBRIDGE • MASSACHUSETTS
PRINTED IN THE U.S.A.

TO
WILLIAM B. STOUT
IN APPRECIATION
OF HIS ACTIVE INTEREST
IN THE PROMOTION OF
MODEL AVIATION

PREFACE TO THE SECOND EDITION

SINCE the publication of the first edition in 1928 the art of making model airplanes has made such astonishing strides that a thorough revision of this book, embodying the latest developments, has seemed absolutely necessary. This revision has included not only many minor changes throughout, but also the practical rewriting of the chapters on Airfoil Sections, Wing Construction, Propellers, the Outdoor Twin Pusher, and Scale Models, and the writing of nine entirely new chapters --- The Senior R.O.G., The Mystery Tractor, The Culver Indoor Tractor, The Mott Pusher and Tractor, The Chaffee C-4 Indoor Fuselage Model, Burnham's Outdoor Fuselage Model, The Howell Helicopter, Gliders and Gliding, and The A.M.L.A. Soaring Glider. Besides these a chapter entitled 'Rules and Suggestions for Conducting an Airplane Model Contest' takes the place of the much briefer 'Rules for Model Airplane Contests' formerly included in the Appendix.

The first step in the final testing of any new invention is the building of a working model. If the model doesn't work, the invention is a failure. If the model does work, so will the larger machine. The correct approach to any mechanical science is through model building.

In aeronautics this is particularly true. You build balsa and tissue ships, power them with rubber, fly them

— and in a few weeks you are talking intelligently about lift, drag, torque, wing-loading, and center of gravity.

Model aviation has developed unbelievably in the last four years. Merrill Hamburg, author of this book and secretary of the Airplane Model League of America, has followed every step in the development. He has been present at every National A.M.L.A. contest and witnessed the setting of the present world's records.

In this book he describes the best models that have been built up to now. The 12-minute indoor endurance ships of 1930, the outdoor fuselage models that will fly in a stiff breeze, the increasingly popular indoor fuselage ships, scale models of the best large aircraft — they're all included in this book, for you to build and enjoy.

GRIFFITH OGDEN ELLIS

DETROIT, *October*, 1930

PREFACE

THE rise in popularity of model airplane construction, during the past two years, has been tremendous. There probably isn't a town or village in the United States where at least one parlor hasn't taken on the semblance of an airport. Thousands of schools are adopting model aviation in their manual training departments, either as a regular or spare-time study. More than thousands of basements are being converted into airplane factories.

The reason for this popularity isn't hard to find. Many leaders in aviation testify that they got their start by building and flying models. There's a fascination in the little ships that fly so smoothly and gracefully. And their construction is within the power of any boy or girl who has moderate skill in handling a few simple tools.

Mr. Merrill Hamburg's many years of experience in teaching model aviation in Detroit public schools, and his wide contacts as secretary and technical adviser of the Airplane Model League of America, qualify him eminently for the authorship of this book. Many of you already know him as the writer of the series of airplane model articles that have appeared in *The American Boy*.

The book fills a long-felt want in the library of the air. In it, you will be introduced to the types of models that have set world's records. As you build them, you will be

following in the footsteps of Glenn Curtiss, William B. Stout, John Carisi, and other great designers of modern aircraft who began their careers by constructing and flying models.

GRIFFITH OGDEN ELLIS

Editor of The American Boy

Vice-President of the Airplane Model League of America

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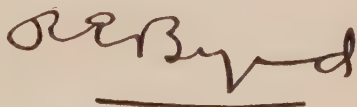
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AN INTRODUCTION

BY COMMANDER RICHARD E. BYRD

FEW activities will so certainly guarantee the progress of aviation in the United States as the building of airplane models. The model aviators of to-day will be the regular patrons of the airways of to-morrow. From their ranks will come the designers of the new ships of the sky that will supersede present aircraft.

I have watched with intense interest the great growth of the Airplane Model League of America, which is represented by thousands of members in every State of the land. I am glad that Mr. Hamburg, its secretary, is giving builders the results of his years of experience, and I know that his book will be not only a service to every model-builder, but a worth-while spur to the development of aviation in this country.

A handwritten signature in dark ink, reading "R. E. Byrd". The signature is written in a cursive, flowing style. Below the signature is a single horizontal line.

BEGINNING TO FLY



CHAPTER I

HISTORY OF AERONAUTICS

FROM prehistoric time all down through the ages man has looked upon the flying bird with envy. The earliest legends were filled with impossible accounts of man flying through the air, and as time passed these stories grew, often giving the details of the supposed flights. Whether these legends are pure myths, the results of the imaginations of the early bards, well rounded out from telling and retelling, or whether they had their beginnings in man's early experiments in trying to take to the air, cannot be determined. However, there is much in many of these stories that comes under the range of possibility.

Such is the story of Dædalus and Icarus. We can easily conceive of Dædalus, after watching the ease with which birds were able to fly, deciding he too could fly by fashioning a pair of wings. What would be more natural than that Icarus, knowing his father's plans, should desire to be first to fly, and that, securing the wings, he should proceed to a near-by cliff for the take-off. Jumping from the precipice, he falls to his death on the rocky shore of the sea that to this day bears his name. The

legend as we know it to-day could easily have been woven about such a simple happening.

Other stories, whether pure myths or based on facts, bear out the desire of man to fly. There is the rather humorous account of Simon the Magician being prayed down to his death by the Apostle of the Lord. One version has it that it was Saint Peter, and the other, Saint Paul, that did the praying, but both versions agree that it was Simon's neck that was broken when he fell into the Roman Forum, having been stopped midway in a successful flight by the heavenly intervention at the behest of the Saint. Again there is the incident of the Saracen of Constantinople, who, by the aid of a long robe stiffened by rods, hoped to be able to fly around the Hippodrome. It is said that he jumped from a tower and at first rose into the wind like a bird, but, losing his momentum, fell to his death. Such are stories, half legend and half history, that are handed down to us of man's early desire to fly.

The first scientific investigator whose work stands to-day was Leonardo da Vinci. He not only stated some of the basic principles of artificial flight, but found time to make many drawings and sketches which bear a surprising resemblance to some of the first successful aeroplanes. He is credited also with the invention of the helicopter and the parachute and is said to have made successful models of both of these. This is indeed remarkable when we realize that, although da Vinci's chief fame rests on his ability as an artist, he was also famous in his day as an architect, engineer, and scientist, making many contributions to each of these fields.

It remained for Francesco Lana in the seventeenth century to propose the first lighter-than-air craft. His plan, although impossible, is highly interesting, as it shows a surprising degree of scientific thought and research. By exhausting the air from globes constructed of thin copper he hoped to obtain a buoyant force sufficient to lift a ship containing men. This ship was to be propelled by sails and oars. Of course his whole theory was impracticable, because of the fact that such a globe will collapse when the air is exhausted from it.

The first successful balloon was constructed by the Montgolfier brothers, who became interested in the subject upon observing that a skirt hung on a line over a fire to dry, would, when filled with hot air, rise until it overturned and allowed the air to escape. They experimented with paper bags which they developed into small balloons and finally decided to build a large one.

On June 5, 1783, a large crowd assembled at Versailles to see the first balloon flight. This first hot-air balloon traveled several miles, and on landing was completely destroyed by the peasants, who thought it was a monster from the upper regions. Not long after this the brothers sent up another balloon carrying live passengers, a sheep, a rooster, and a duck making up the aërial passenger list. This flight was made to determine whether life could exist in the rarefied air above the earth. Although the flight was successful, the question arose as to the possibility of man not being able to live, even though the animals did. It was finally determined to test this by strapping two condemned criminals to a

balloon. They reasoned that, as the men were condemned to death, nothing would be lost if they were killed. However, they did give the men a faint ray of hope by promising them their freedom in case of a successful flight. But, when everything was ready, one Pilâtre de Rozier protested against allowing the honor of the first flight by man to go to criminals, and announced his willingness to undertake the trip. Over his protests he was prevailed upon by his friends to make the first attempt in a balloon held down by ropes. In November, 1783, he made the first flight in a free balloon that history records. Later in the same year the Montgolfier brothers furnished the bag and a French chemist, named Charles, supplied the hydrogen for the first hydrogen balloon. These flights definitely divided aeronautics into two distinct fields, namely, lighter-than-air craft and heavier-than-air craft.

Following this period there were many theories advanced and experiments made in aviation; while some were practicable, others were very impracticable. In 1840 George Pocock, of Bristol, invented the first man-carrying kite and successfully demonstrated it, raising a passenger as high as a hundred yards from the ground. He was closely followed by Henson and John Stringfellow, who built the first steam-driven monoplane. This first ship, although a failure, encouraged Stringfellow to continue experimenting, and in 1848 he built and successfully flew a similar type of ship, but of smaller design.

After Stringfellow gave up his work there was a long period in which very little was accomplished in the science

of aviation. Toward the latter part of the nineteenth century there was considerable work done with gliders. The most important was done by Lilienthal in Germany, by Le Bres in France, by Pilcher in England, and by Chanute, Montgomery, and the Wrights in America. Space does not permit us to go into detail regarding the work of each of these, but in passing we should point out that the knowledge gained from these experiments with gliders made the power-driven aeroplane possible.

Dr. Samuel P. Langley began a series of experiments about 1891 with rubber-driven models which demonstrated the practicability of heavier-than-air machines. Later he made some very successful steam-driven models that flew almost a mile. The success of these models determined Langley to build a man-carrying machine.

In October, 1903, all was ready for the test, the engine started, and everything working fine, when on leaving the track the plane was caught and dumped ingloriously into the water. It was given a second test on December 8, 1903, only to have a similar accident, almost completely wrecking it and causing it again to drop into the river. In both of these flights the method of launching was from a track built on the roof of a house boat.

Just nine days later, December 17, 1903, the Wright brothers made their first power-driven flight and the conquest of the air was completed. It is interesting to note that the story is told that these brothers, while mere boys, were interested in the study of aeronautics, upon being presented with a small toy helicopter by their father. The first flight was the result of years of study and nu-

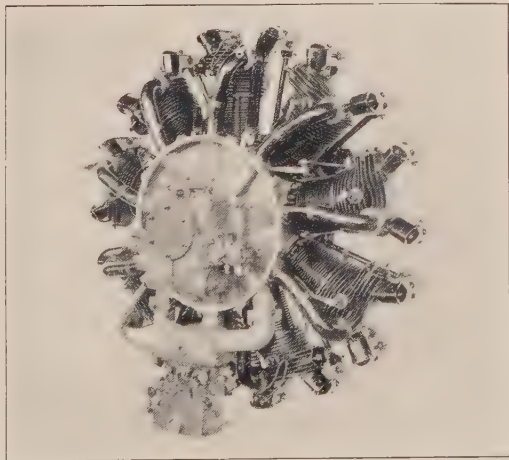
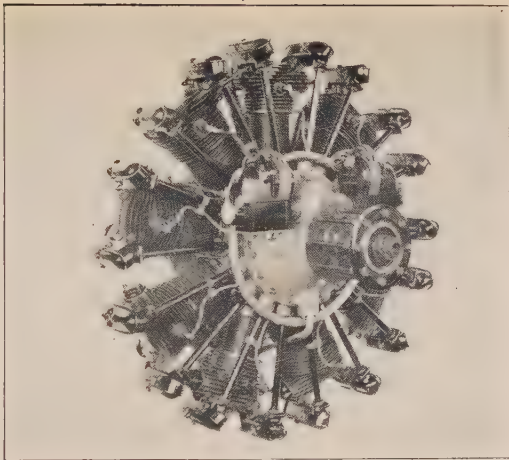
merous experiments with gliders. When they had secured sufficient information to warrant a trial flight, they began looking around for a power plant. As there was not an engine available, suitable for their purpose, they decided to build one. It is said that a certain engine manufacturer refused to accept the job, as he would not have his men waste their time building an engine for such useless experiments. In their first trials the brothers, between them, made four successful flights, the first of only twelve seconds and the last and longest of fifty-nine.

The machine was taken back at the end of these tests to their camp and left supposedly in safety. A sudden gust of wind caught and overturned the plane before any one could reach it, so completely wrecking it that it was useless for further experiments.

By continuing their investigations and improving their machine, the Wright brothers were able, by July, 1909, to pass the tests for a successful aeroplane as prescribed by the United States Government. To pass these tests the ship had to be capable of carrying two men with a flying range of one hundred and twenty-five miles at forty miles an hour.

It seems almost impossible that the present aeroplane could be developed from the original Wright plane in the twenty-five years since the first flight.

Immediately following the feat of the Wright brothers, interest in aviation became very marked, especially in Europe. During the years of 1903-11 there were numerous experiments and investigations carried on by such men as Louis Blériot, Maurice Farman, Hubert Lathan,



TWO VIEWS OF WRIGHT WHIRLWIND J-5
NINE-CYLINDER AIR-COOLED RADIAL
ENGINE, RATED H.P. OF 210 AT 1800
R.P.M.

Alberto Santos-Dumont, the latter being the next to accomplish power-driven flight. In America, Glenn Curtiss, Dr. Alexander Bell, and two associates organized the Aërial Experiment Company. S. F. Cody was another pioneer in aviation that should be mentioned; an American by birth, but a British subject, he was the first to fly in England. His unusual ability as a flier and his great daring attracted attention throughout Great Britain. Just to mention all the famous flights and fliers of this time would fill volumes, and in order to get as much as possible into one chapter the most noteworthy of these events will be given in a short summary in the order in which they took place.

Undoubtedly the World War gave a greater impetus to the advancement of aviation than any other event before or since. Up to this time the airplane's value as a weapon had not been fully realized and very little had been done directly by any government to materially advance its development. Very early in the war, however, it became evident that the side which held the balance of power in the air would have a distinct advantage. As soon as this was realized the race for supremacy was on, and the warring factions put their best brains to developing the airplane and its accessories. The most outstanding achievements of this period were: the development of aërial photography; the successful designing of large ships for bombing; a system of gearing the timing mechanism to machine guns, called synchronization; permitting the guns to be fired between the revolving blades of the propeller without injury to them; the advancement made in

building inherent stability into the planes; the great improvement in the design of airplane engines both from the standpoint of power and reliability; and last but not least the great strides that were made in the art of flying by individual pilots. This last was due largely to the necessity for a pilot to be able to get the maximum from a ship under all conditions. Rookie flyers were taught to do stunts that before the war were seldom tried by the oldest veterans.

Since the war aviation has advanced steadily, especially in the commercial field. As evidence of this we have in America the highly developed air mail system, a number of passenger-carrying transport lines, and an increasing number of firms and individuals using the air for rapid transportation of parcel goods. Europe has its large and ever-increasing number of passenger lines, meeting their schedules day after day in all kinds of weather in a way that rivals the railways and with the added element of speed with its saving of time.

The most discussed events that have taken place in aviation since the war have been the numerous long flights. For the most part these have been very successful, especially where proper preparations were made beforehand, and have proved the reliability of the airplane far beyond the dreams of the early pioneers. It is the opinion of many of the leaders in aviation, however, that long and dangerous flights should be discouraged, as they bring more adverse criticism of the industry when unsuccessful than favorable comment when they are successful. These long-distance flights began shortly after the close

of the war with the successful crossing of the Atlantic by Commander Read, of the United States Navy, in the flying boat NC-4 during May, 1919; they reached the peak in 1927 with the numerous attempts at non-stop flights.

A history of aeronautics would not be complete without at least a short account of the development of aerostatics, lighter-than-air craft. As stated at the beginning of the chapter, Lana was the first to propose a definite design for this type of ship, while to the Montgolfier brothers goes the credit of constructing the first successful balloon. This definitely divided the field of aeronautics into two distinct groups; that is, aviation, the art of operating heavier-than-air craft, and aerostation, the art of operating lighter-than-air craft.

Shortly after the discovery of hydrogen by Cavendish in the year 1776, experiments were made with the new gas for filling small balloons. The first large balloon to use hydrogen was constructed by the noted aeronaut Charles. By treating a half-ton of iron filings with a quarter-ton of sulphuric acid, he generated enough hydrogen in four days to make a very rapid ascent, using a rubberized silk bag. As this balloon was not provided with any means by which the gas could escape, it probably burst on reaching a high altitude.

During the latter part of the eighteenth century ballooning became very popular. Clubs were organized and many contests held. It was during this period that Blanchard succeeded in crossing the English Channel in a balloon. Rozier, the first man to pilot a free balloon, was killed trying to duplicate the feat with one, so con-

structed that hydrogen was contained in the top section and hot air in the lower. The explosion occurred high in the air, when hydrogen, leaking into the lower section, was ignited by the heating device. Thus the first man to make a balloon flight also became the first victim of aeronautics.

A French general called Meusnier was the first to propose a dirigible, a balloon that could be driven and steered in any direction the operator wished. His plan called for a rigid connection between the control car and the bag, both to be elliptical in shape, to cut down resistance, and for three propellers driven by hand, requiring a crew of eighty men. The balloon was never constructed, but many of his ideas were used and proved practical in later ships. Giffard, an inventor, using the elliptical bag with a steam engine for power was the first to build and fly such a ship. There were a number of similar experiments, more or less successful, made with dirigibles about this time. The two most successful designers, Zeppelin in Germany and Santos-Dumont in France, began their work toward the end of the nineteenth century.

Dumont, a Brazilian, had constructed fourteen dirigibles in all before he gave up building lighter-than-air craft to work on airplanes, on learning of the success obtained by the Wright brothers. A very interesting account of his experiments is given in his book, 'My Airships.' His first ship, a small one, powered with a three horse-power motor, made only one successful flight. He built ship after ship with various improvements, and demonstrated their reliability by a great many flights. It

is told that he amazed and delighted the Parisians by flying from his country home to his city residence for breakfast and, after the completion of the meal, back again. He even went so far as to design types, much as the automobile manufacturers do to-day. At one time he had as many as three, an omnibus, a racing ship, and a town runabout. All these ships were of the non-rigid type.

Ferdinand von Zeppelin, a retired German army officer, began work on his first airship in 1898. This ship, the first rigid dirigible ever built, was constructed with an aluminum framework covered with fabric. Two control cars were rigidly attached to the framework, each containing a sixteen horse-power motor used in driving the propellers. This ship was able to make over twenty-one miles an hour. Zeppelin set out immediately to construct a second ship, which was followed by the construction of numbers three and four. All of these ships were given the name of Zeppelins and proved so reliable that when number four was destroyed in a storm, enough money to continue the work was quickly raised by popular subscription. A company was organized to direct the expenditure of this money which immediately began operation by securing an experimental field and by the construction of a factory. The Zeppelin Company soon began establishing landing-fields and started a regular passenger service. The improved Zeppelin provided many comforts that were unthought of up to that time in any type of aircraft. At the outbreak of the World War, Germany had thirty of these ships for military purposes. Most of the airships that have been built since the beginning of the

war are more or less in imitation of the Zeppelins. The most outstanding flights made by these will be found in the following summary in the order that they were made.

AVIATION

SUMMARY OF IMPORTANT EVENTS

December 19, 1903

Orville Wright made the first flight in power-driven airplane.

The plane, called the Kitty Hawk, flew 852 feet.

September 26, 1905

Wrights made the first officially recorded flight at Dayton,

Ohio. Distance 11.12 miles. Time 18 minutes, 9 seconds.

* September 14, 1906

Alberto Santos-Dumont succeeded in making a flight of eight seconds. He was first to succeed after the Wright brothers.

April 5, 1907

Louis Blériot made a flight of six seconds.

October 15, 1907

Henry Farman made his first flight of 935 feet, using a Voisin biplane.

October 25, 1907

Farman made first turn in the air.

March 29, 1908

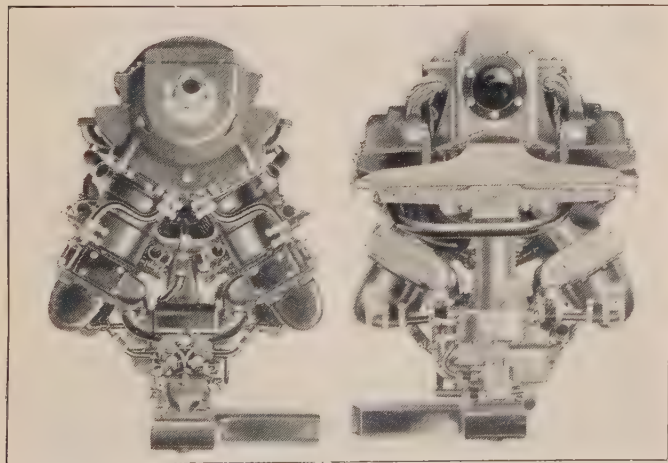
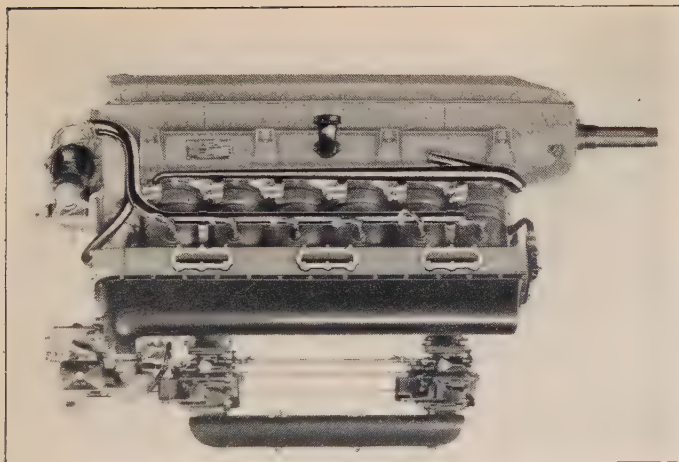
Farman, carrying Léon Delagrangé, made the first recorded flight with passenger.

July 8, 1908

Léon Delagrangé made the first flight with a woman, Madame Peltier, as passenger.

September 12, 1908

Orville Wright crashed his machine at Fort Meyer, Virginia, resulting in the first airplane fatality. Wright was severely injured and his passenger, Lieutenant Selfridge, was killed.



PACKARD MODEL 2A-1500 INVERTED AIRCRAFT ENGINE
 Bore $5\frac{3}{8}$ in.; stroke $5\frac{1}{2}$ in.; displacement 1530 cubic in.;
 rating 600 B.H.P. at 2500 R.P.M.

July 25, 1909

Louis Blériot made first airplane flight across the English Channel.

August 22, 1907

Opening day of the first airplane meet. The meet was held at Rheims, lasting one week, with thirty entrants contesting.

August 28, 1909

Glenn Curtiss at the Rheims meet won the first Gordon-Bennett cup.

September 17, 1911, to November 5, 1911

First transcontinental airplane flight in America, a distance of 3390 miles by C. P. Rogers. Flight started in New York and ended in Pasadena.

May 28, 1914

Glenn Curtiss flew the reconditioned but original Langley plane for a distance of 150 feet at Lake Keuka. About the only change was the addition of floats.

1914 to 1918

Period of World War. So many events happened during this time that it would be impossible to attempt to give them in so limited a space. Only a few of the most famous aviators of the war are given.

American aviators

Captain E. V. Rickenbacker — 26 victories. Squadron Commander 94th Pursuit (Hat-in-the-Ring Squadron).

Frank Luke — 18 victories in two months.

Major Raoul Lufbery — 17 victories officially credited to him; the actual number was over twice this many, but not confirmed.

British aviators

Captain Albert Ball — 44 planes.

Colonel William Bishop — 72 planes — known as 'Ace of Aces.'

French aviators

Captain George Guynemer — 53 victories.

Captain René Fonck — 75 victories.

Captain Charles Nungesser — 36 victories.

German aviators

Captain Freiherr von Richtofen — 80 victories, Commander Famous Flying Circus.

May 8 to May 31, 1919

Lieutenant Commander Read made first trans-Atlantic flight from Rockaway, by way of Newfoundland, The Azores, Lisbon, and then to Plymouth, England, where the flight ended. The ship used was the NC-4 seaplane equipped with four Liberty motors each developing 350 horse-power.

June 14, 1919

Captain Alcock and Lieutenant Brown, Englishmen, made the first direct crossing of the Atlantic from Newfoundland to Ireland, a distance of 1880 miles. Time approximately 16 hours.

October 8 to October 16, 1919

Lieutenant B. W. Maynard flew from the Atlantic to the Pacific and return. Time 9 days, 4 hours, 26 minutes.

November 12 to December 10, 1919

First flight from England to Australia. Pilots Sir Ross Smith and his brother Sir Keith Smith. Distance 11,060 miles.

July 15, 1920

U.S. Army Alaskan flight, New York to Nome and back to New York. Distance over 7000 miles. Trip successfully completed by all four planes.

May 2 and 3, 1923

Non-stop transcontinental flight by T-2 from Mitchel Field, New York, to Rockwell Field, San Diego. Pilots Lieutenants Macready and Kelly. Time 26 hours, 50 minutes. Distance 2550 miles.

June 1, 1923

Lieutenant Maughan made first dawn to dusk flight from New York to San Francisco. Total distance 2670 miles. Time 21 hours, 48 minutes.

August 27, 1923

First refueling in the air from one airplane to another. Pilots Captain L. H. Smith and Lieutenant J. P. Richter.

April 6 to September 28, 1924

First round the world flight by four United States Army Air Service planes. Distance 28,000 miles. Time 5 months, 24 days. Actual time in air 371 hours, 11 minutes. Planes, Douglas biplanes.

January 29, 1926

Lieutenant John A. Macready established and set new altitude record at McCook Field, Dayton, Ohio, reaching a height of 38,704 feet.

May 9, 1926

Commander Byrd and Floyd Bennett flew from Spitzbergen to North Pole and return. Time 15 hours.

April 12 to 14, 1927

Clarence Chamberlin and Bert Acosta established American endurance record of 51 hours, 12 minutes.

May 21-22, 1927

Colonel Charles A. Lindbergh made first New York to Paris flight. Distance 3600 miles. Time 33 hours, 29 minutes, 30 seconds. Ryan monoplane equipped with Wright Whirlwind Motor.

June 4-5, 1927

Clarence Chamberlin, with Charles Levine as passenger, flew from New York to Helfta, Germany. Distance 3905 miles. Time 42 hours, 45 minutes, 30 seconds.

June 28, 1927

Lieutenants Lester J. Maitland and Albert Hegenberger, in a Fokker three-motored (Wright Whirlwinds) army transport, flew from Oakland, California, to the Island of Oahu, Hawaii. Time 25 hours and 50 minutes.

June 29, 1927

Commander Richard Byrd, Lieutenant Bertram Acosta, Lieutenant George Neville, and Lieutenant Bernt Balchen flew the three-motored Fokker America to France from the United States. Out of gas and lost in fog, a forced landing was made at Ver-sur-Mer, a small town 125 miles from Paris. Distance 4200 miles, time 40 hours.

July 14, 1927

Ernest L. Smith and Emory B. Bronte flew a Travel Air Monoplane, The City of Oakland, from Oakland, California, to the island of Molokai, Hawaii. Time 25 hours, 36 minutes. Distance 2348 miles.

July 20, 1927

Colonel Lindbergh began his tour of the country under the auspices of the Guggenheim Fund. Visited 82 cities, all 48 States. Distance 22,350 miles.

August 17, 1927

Arthur C. Goebel won first place in Dole flight from Oakland, California, to Hawaii. Time 26 hours, 17 minutes, 33 seconds, Woolaroc Monoplane.

August 17, 1927

Martin Jensen, pilot, and Paul Schluter, navigator, won second place in the Dole race. Time 28 hours, 16 minutes. Breese Monoplane.

August 28—September 14, 1927

Edward F. Schlee and William S. Brock began their round-the-world flight from Harbor Grace, Newfoundland, across the ocean, Europe, Asia, to Japan. Distance 12,295 miles. Time 18 days — 145½ flying hours.

October 11-13, 1927

George W. Haldeman and Ruth Elder attempt New York to Paris flight which ended by forced landing at sea. Flight set new over-water record of 2623 statute miles.

December 14, 1927, to February 13, 1928

Colonel Charles A. Lindbergh made Pan-America Good-Will trip. Non-stop flight from Washington, D.C., to Mexico City. Visited fifteen nations and dependencies in a circuitous route through Central and South America and the West Indies. Trip finished in non-stop flight from Cuba to St. Louis. Total distance of tour 9000 miles.

April 12-13, 1928

Herman Koehl and Baron Ehrendfried Guenther von Huenefeld, of Germany, and Commandant James Fitzmaurice,

of Ireland, make first westbound Atlantic flight from Dublin, Ireland, to Greeneley Island, Newfoundland. Junkers Monoplane Bremen. Time 36 hours, 30 minutes.

June 17, 1929

Miss Amelia Earhart, Wilmer Stultz, pilot, and Louis Gordon, mechanic, flew from Trepassey Bay, Newfoundland, to Burry Port, Wales. First non-stop Atlantic flight by a woman. Time 20 hours, 40 minutes.

June 27-28, 1929

Captain Frank M. Hawkes made non-stop flight from Roosevelt Field, Long Island, to Los Angeles. Time 19 hours, 10 minutes. Lockheed Vega.

June 28, 29, 1929

Captain Frank Hawkes, after seven hours' rest, made the return flight from Los Angeles to Roosevelt Field, Long Island. Time 17 hours, 43 minutes. Elapsed time coast-to-coast 43 hours, 59 minutes.

July 13-30, 1929

Dale Jackson and Forest O'Brine set a new refueling endurance record of 420 hours, 21 minutes, and 30 seconds; almost 17 days. Curtis-Robertson powered with a Curtiss Challenger 170 H.P. radial engine.

September 25, 1929

Lieutenant James H. Doolittle took off and landed an airplane absolutely blind, depending entirely on his instruments.

October 21, 1929

German seaplane D.O.X. took off from Lake Constance for one hour flight with 150 passengers and a crew of ten. Weight 52 tons. Reached a cruising speed of 110 m.p.h.

November 29, 1929

Commander Richard E. Byrd, Bernt Balchen, pilot; Captain Ashley McKinley, aerial surveyor, and Harold I. June, radio operator, reached the South Pole on a flight which began at Little America, the Byrd Antarctic Expedition's base.

AEROSTATICS

SUMMARY OF IMPORTANT EVENTS

1776

Cavendish discovered hydrogen.

June 5, 1783

Montgolfier brothers made first public exhibition.

August 29, 1783

A chemist named Charles made the first successful hydrogen-filled balloon exhibition.

September 19, 1783

Montgolfier brothers sent up first balloon carrying live passengers; a sheep, a duck, and a cock.

October 15, 1783

Pilâtre de Rozier made the first balloon ascension.

November 21, 1783

Pilâtre de Rozier and the Marquis d'Arlandes made the first ascension in a free balloon.

December 28, 1783

James Wilcox of Philadelphia made the first free balloon ascension in America.

January 17, 1785

Jean-Pierre Blanchard and Dr. Jeffries, an American, made the first crossing of the English Channel in a free balloon.

July 16, 1785

Pilâtre de Rozier with a companion was killed when their hydrogen balloon exploded while in the air in an attempt to cross the English Channel.

1852

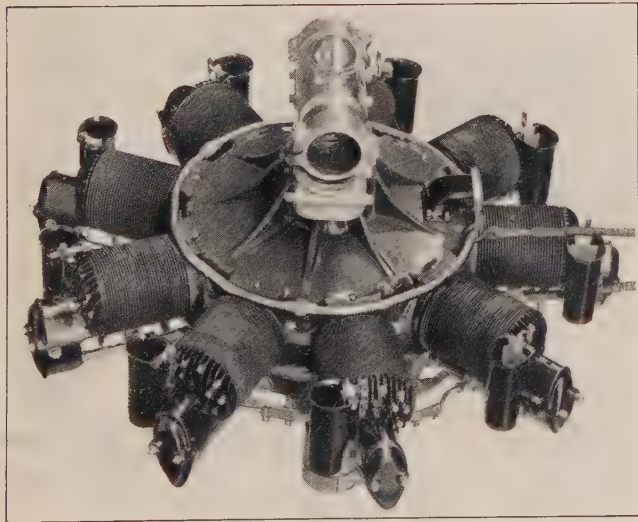
Giffard built and successfully operated the first power-driven balloon.

September 20, 1898

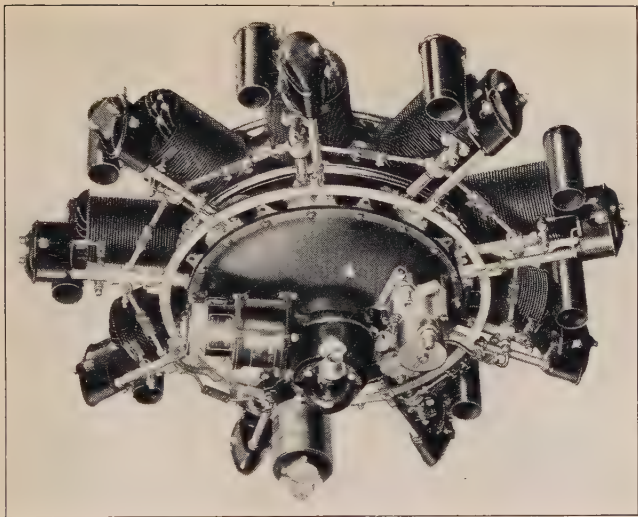
Santos made his first successful flight in his non-rigid type of dirigible.

July, 1900

Ferdinand von Zeppelin made his first flight in his rigid type airship.



Front view



Rear view

PACKARD DIESEL AIRCRAFT ENGINE

November, 1917

The German airship L-59 made its memorial non-stop flight to relieve German troops in East Africa. Load carried fifty tons. Distance covered 4225 miles.

July 2-13, 1919

Major G. H. Scott flew across the Atlantic from England to New York in the R-34 with a crew of thirty. The trip from England to New York took 108 hours, 12 minutes. The return trip was made in 75 hours, 3 minutes.

October 12-15, 1924

Flight of the ZR-3 (Los Angeles) across the Atlantic Ocean to Lakehurst. Distance 5066 miles. Time 81 hours, 17 minutes.

May 11, 1926.

Italian airship Norge, with Amundsen, Ellsworth, and Nobile, left Spitzbergen for the flight across the North Pole to Nome, Alaska.

October 11-15, 1928

Graf Zeppelin, German Zeppelin, with crew of forty and twenty passengers, made trip from Friedrichshafen, Germany, to Lakehurst, New Jersey, via Mediterranean and Bermuda. Time 111½ cruising time.

October 29—November 1, 1928

Graf Zeppelin made return flight to Friedrichshafen. Time 71 hours, 12 minutes.

July 31—August 4, 1929

Graf Zeppelin with Dr. Hugo Eckener in command, with twenty passengers, made second flight from Friedrichshafen, Germany, to Lakehurst, New Jersey. Time 93 hours. Estimated mileage 5331 land miles.

August 8-29, 1929

Graf Zeppelin made round the world flight by way of Germany, Russia, Tokio, Los Angeles, and Lakehurst. Time 21 days, 7 hours, 34 minutes. Approximate mileage 19,300 miles.

September 4, 1929

Graf Zeppelin arrived home port at Friedrichshafen 67 hours after leaving Lakehurst. Mileage from Friedrichshafen to Friedrichshafen 21,238 miles.

CHAPTER II

AIRCRAFT AND POWER PLANTS

THE science of aeronautics is divided into two general classes, according to the method depended on to obtain the lift or buoyant force necessary to sustain the craft while in the air. The first class is known as aviation, the art of operating heavier-than-air craft which receive their lift from aerodynamic forces. The second is known as aerostation, the art of operating lighter-than-air craft. These are sustained in the air by the buoyant force of gases. Heavier-than-air craft can remain in the air only when in motion, while lighter-than-air craft can remain stationary in the air when the lifting or aerostatic forces are equal to the weight of the entire craft including equipment and crew, or while anchored.

The spherical or free balloon, the non-rigid and the rigid airship, are the best examples of lighter-than-air craft. The pilot of the free balloon is more or less at the mercy of the winds; although he may select or find a favorable wind he never is sure how long it will last. Because of this the balloon is used mainly for scientific investigations and by sportsmen. Realizing the necessity of being able to guide the flight of a balloon, the earliest pilots began experimenting with methods by which they could gain directional control. The dirigible or steerable balloon has been evolved from these experiments. These

in turn are divided into the non-rigid, semi-rigid, and the rigid airships.

Non-rigid dirigibles are usually composed of an elongated bag, supporting, by means of ropes or cables, a control car, equipped with engines and propellers.

The semi-rigid differs from the non-rigid airship in that it has a rigid frame or keel running from the nose to the stern. This stiffens the entire bag, helping it to retain its shape as well as distributing evenly throughout the bag the weight of the gondolas, or control cars. The Italians are the foremost advocates of this type of ship.

The rigid airship has a rigid framework covered with fabric and contains gas bags or cells. Control cars are attached by means of solid supports to the framework. Count von Zeppelin built the first rigid airship and without doubt has contributed more to the success of this type of aircraft than any other person.

The following types of aircraft are classed under the heading of aviation: the kite, the parachute, the glider, the ornithopter, the helicopter, and the airplane. The first two are familiar and need no introduction. The glider is a form of airplane without a power plant, and like the airplane it cannot remain in the air unless in motion relatively to the air. Gliding flights are as a rule started from the top of a hill, allowing the machine a chance to gain speed by losing altitude. By taking advantage of the shifting air currents, experienced pilots have been able to keep their gliders in the air for hours at a time. Aircraft designed to fly by flapping wings, similar to the flight of birds, are called ornithopters. Although

the earliest experiments by men in aviation were with this type of machine, so far, because of structural difficulties, none of these have been successful. It has been often pointed out that one of the chief reasons why the airplane has not been more popular is due to the fact that one must have the use of a large landing-field wherever one flies. Many attempts have been made to develop a ship that would rise vertically. This would, of course, do away with the necessity of a large airport. Although as yet of no commercial value, a number of these experiments have been successful. The lift for most of these is derived from rotating airfoils or wings similar to propellers. Such a ship is called a helicopter. The airplane, familiar to every one, is the most important of the heavier-than-air craft. It may be defined as a mechanically driven heavier-than-air craft, fitted with fixed wings and supported by the action of the air on these.

When an airplane has but one wing, it is known as a monoplane; when it is equipped with two wings, it is called a biplane; likewise when with three wings, a triplane, and when with more than three, a multiplane. If the propellers are placed in front of the wings, the airplane is called a tractor; when the propellers are placed behind the wings, it is said to be a pusher. When the airplane is equipped as both a pusher and tractor, it is said to be a combination. Airplanes are also spoken of as single-engine and multi-engine, depending on whether they have one or more engines.

Some airplanes are equipped to take off and land on water; these are known as seaplanes. If the plane is

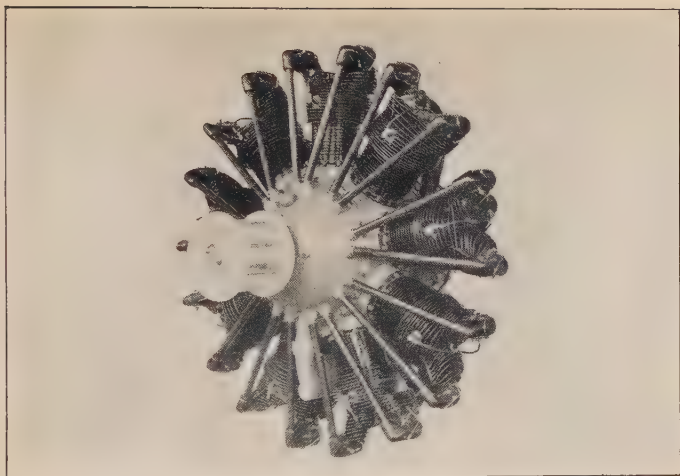
equipped with floats, it is said to be a hydroairplane. Some seaplanes are equipped with a hull or boat-like structure that furnishes buoyancy when in contact with the surface of the water. It usually contains accommodations for the crew and passengers and as a rule serves as both float and fuselage. This type of seaplane is called a flying boat. An airplane equipped with both floats and wheels and designed to rise from, and alight on, either land or water, is called an amphibian.

All internal combustion engines used in airplanes are generally classified according to the method of cooling. These are again classified with reference to arrangement of the cylinders and cam shaft. Both the water-cooled and air-cooled engines have their advantages and disadvantages. The air-cooled engine is generally conceded to have the following advantages over the water-cooled:

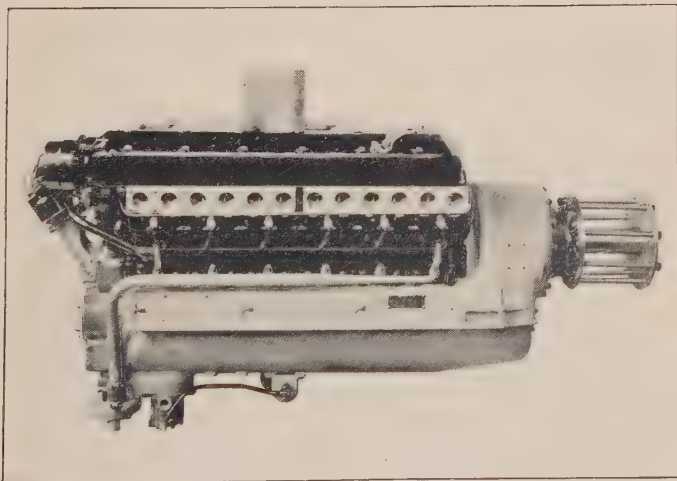
a. The air-cooled engine transfers the heat of combustion from the cylinders to the atmosphere. The water-cooled engine transfers this heat to the cooling water and then by means of a radiator to the atmosphere. Because of the elimination of the heavy cooling system the air-cooled motor is much lighter.

b. The air-cooled motor, being much lighter, permits a considerable saving in the weight of the entire airplane construction.

c. The parts of an air-cooled motor are more accessible, cylinders and their accessories are interchangeable, and any one may be removed without interfering with the adjacent cylinders. The air-cooled engine as a rule can be completely overhauled without removing from the plane.



PRATT & WHITNEY 400-H.P. 'WASP'



CURTISS GEARED V-1550 WATER-COOLED ENGINE
Develops 575 H.P. at 2500 R.P.M. Displacement 1550 cubic inches

Engines are classified according to the arrangement of their cylinders. The following definitions explain the different types:

Barrel type engine — An engine having its cylinders arranged equidistant from and parallel to the main shaft.

Radial engine — An engine having stationary cylinders arranged radially around a common crank shaft.

Rotary engine — An engine having revolving cylinders arranged radially around a fixed crank shaft.

Inverted engine — An engine having its cylinders below the crank shaft.

Vertical engine — An engine having its cylinders arranged vertically above the crank shaft.

V or Vee engine — An engine having its cylinders arranged in two rows so that an end view of the motor forms a letter 'V.'

W engine — An engine having its cylinders arranged in three rows so that in the end view they form a letter 'W.'

X engine — An engine having four rows of cylinders whose axes meet at the crank shaft center in a manner resembling the letter 'X.'

Flat engine. An engine having cylinders arranged in two rows on opposite sides of the crank shaft.

The selection of engines for any given airplane depends on a number of factors, such as speed, power output, torque curve, balance, cooling, and the convenience of arrangement. A complete discussion of these characteristics for the different types of engines may be found in a number of books on this subject.

Because of the elimination of the complicated cooling system, which is the source of thirty per cent of the forced landings in airplanes using this type of engine, the air-cooled motor is more reliable. Performance seems to show that the air-cooled motor does not need overhauling as often as the water-cooled engine. It is not uncommon for one to run over three hundred hours without any major adjustments being made.

The air-cooled motor warms up much faster than the water-cooled. The water-cooled motor has its chief advantage in that it lends itself more readily to the design of the entire airplane. With this type of engine the fuselage may be stream-lined and the resistance of the entire plane reduced materially. In the larger air-cooled motors the diameter often offers considerable resistance in addition to blanketing the propeller.

A number of photographs, showing representative engines of the different types, are given. All of these engines have made excellent records in their class and are considered very highly by the aeronautical industry.

CHAPTER III

AIRFOIL SECTIONS

WE are apt to think of air as something that has neither weight nor volume, but this is not so. Air is a mixture of a number of gases, the greater part being nitrogen and oxygen. Under standard conditions, 0°C. , and 760 mm. pressure, air weighs $1/773$ as much as an equal volume of water.

Archimedes' principle, that the buoyant force exerted upon a body immersed in a fluid is equal to the weight of the fluid displaced, applies to both air and water. The excess buoyancy, therefore, of any object immersed in air is equal to the weight of the air displaced less the weight of the object. If the object is heavier than the weight of air displaced, it will not float.

In order to secure buoyancy in lighter-than-air craft, envelopes are filled with gases, such as hydrogen or helium, which are lighter than air. If the weight of the gas used is known, the amount of lift of an airship may be calculated by subtracting the total weight of the ship, including the gas used, from the weight of the air displaced.

Example: The weight of a 10,000 cubic foot balloon, including the basket, is equal to 400 pounds. What will be the excess buoyancy in pounds when the balloon is filled with hydrogen?

The weight of dry air is .0766 lb. per cu. ft.

The weight of hydrogen is .0053 lb. per cu. ft.

Lifting power of pure hydrogen is equal to

$$.0766 - .0053 = .0713 \text{ lb. per cu. ft.}$$

Lifting power of hydrogen in general use is only .066

Lifting power of 10,000 cu. ft. of hydrogen in general use is

660 lbs.

Total weight of balloon

400 lbs.

Excess buoyancy

260 lbs.

Then, unless the balloon is held down, it will rise until it reaches an altitude where the weight of the rarefied air displaced is equal to the weight of the balloon. At this altitude it will float along, dropping or rising as it is affected by the atmospheric conditions. If it enters a cool stratum of air, it contracts and descends; if it enters a warm stratum of air or into the sun's rays from under a cloud, it will expand and ascend. The pilot can keep it from descending by dropping ballast, and from ascending too high by opening a valve and allowing some of the hydrogen to escape. In this manner he has a partial control over the direction in which he will go, as he can select different air currents at different altitudes.

The problem of getting an airplane off the ground is more complicated, as the machine weighs more than the air, and the total lift must be derived from other sources. Just how an airplane weighing thousands of pounds can defy the pull of gravity and go flying through the air will always remain a mystery to some folk. The explanation is simplified when we compare the airplane to an aquaplane or surfboard. Every one has seen pictures of men

and women riding these boards, behind speeding motor boats. When the boat stops, the boards sink under the weight of the people riding them.

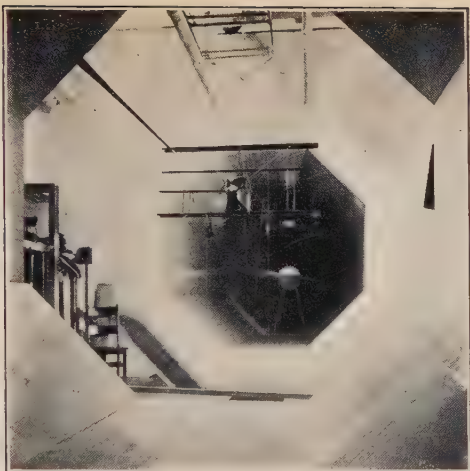
The boards are rarely over four feet square and vary from one or two inches in thickness. Such a board will not displace much over one hundred pounds of water. The useful buoyant force is equal to the weight of the water displaced minus the weight of the board. Let us assume that a board weighs twenty pounds and that it will, when totally immersed, displace one hundred pounds of water. Then the useful lift or buoyancy that can be used to support a person is equal to $100 - 20 = 80$ pounds. Yet this board when towed behind a fast-moving motor boat will support the combined weight of three people, or over five hundred pounds. The board must be receiving from some source an additional lift of $500 - 80 = 420$ pounds. The dynamic forces set up by the board when towed rapidly through the water provide the necessary lift required to support the weight of the persons riding it. The pull on the rope may be likened to the pull exerted on the airplane by the propeller.

Again, if one holds a cardboard or similar material out of the window of a fast-moving car in such a manner that the flat surface is horizontal, it offers very little resistance. Now, if it is inclined so that the front edge is slightly higher than the rear edge, it immediately offers resistance. The card tries to rise and to move backward at the same time. The force tending to raise the card is called lift, and the force tending to move it backward is known as drag. As we increase the angle of inclination,

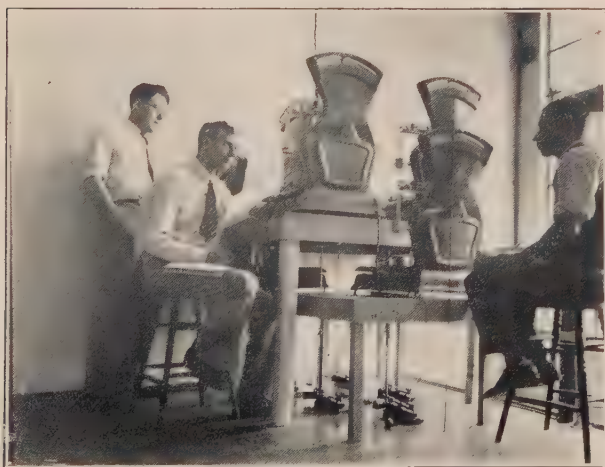
the lift and drag increase. In an airplane we say we have increased the angle of attack or the plane is climbing at a steeper angle.

It is not necessary to move the card in order to obtain lift and drag, as we can obtain the same forces by holding the card in front of an electric fan. This proves that the air forces on a body are dependent on the relative motion of the air with respect to the body. The discovery of this led to the use of wind tunnels for testing airplanes and airplane parts.

Drawing 1 shows the diagram of the wind tunnel at the University of Michigan. This type is known as the double return tunnel, as it is so constructed as to allow the air to keep in circulation. Because of this, a higher wind velocity can be obtained with less effort. The air is drawn through the experimental chamber by the propeller, *A*, driven by the motor, *E*, and continues around either side and back to the throat. The position of the model is clearly shown in the diagram. The photograph shows the tunnel looking from the throat toward the propeller. The wires supporting the model being tested are connected to the balances shown in the other photographs. These balances measure the forces acting on the model, such as the lift and drag, and by determining the resultant of these we can measure the center of pressure travel and other moments that the designer is interested in. The principle of the tunnel is the same as the Venturi tube used in the physics laboratory. The narrow throat increases the velocity and reduces the pressure at that point. Exact wind velocities can be determined by the use of a mano-



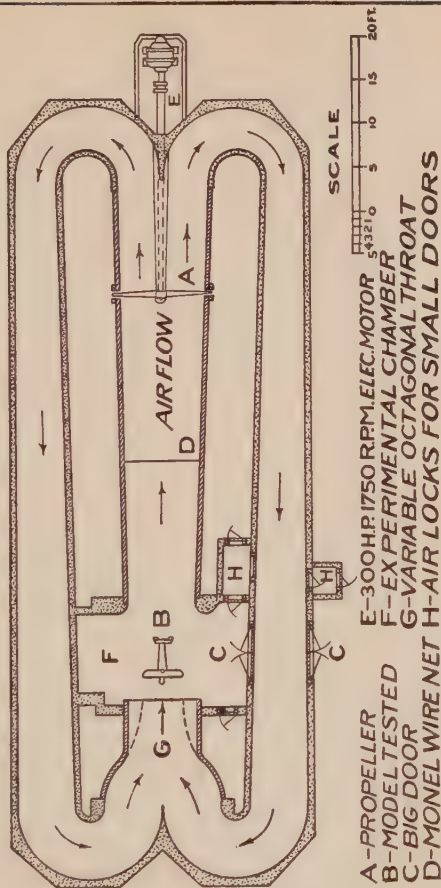
WIND TUNNEL, LOOKING FROM THE
THROAT TOWARDS THE PROPELLER
Note the model suspended in the experiment
chamber



THE BALANCES AND APPARATUS FOR MEASURING
THE FORCES EXERTED ON AN AIRFOIL IN THE
WIND TUNNEL

UNIVERSITY OF MICHIGAN

8-FEET OCTAGONAL WIND TUNNEL



NO. 1

meter to measure the static pressure. A motor control is used to keep constant wind speeds.

The double surface wing was an early development; experimenters, trying to imitate the wings of birds, built up with spars and ribs a cambered or curved surface which they covered on one side only. It was not long before they found that these wings were more efficient when covered on both sides. A cross-section of a wing is known as an airfoil or airfoil section. Drawing 3 shows the names of the various elements of two airfoil sections. These sections are described by giving coördinates of points along the upper and lower surfaces. The coördinates are given in percentages of the chord length.

If one is not familiar with the rectangular coördinates system of plotting curves, the procedure of laying out an airfoil section can be explained as follows: The chord length must be first decided on for the given airfoil and this multiplied by the percentages given in the table (see Drawing 2, under the per cent sign). This divides the chord into a number of stations. The next two columns, marked upper and lower respectively, give in per cent of chord the height of the upper and lower surfaces at their respective stations. The stations are laid out from the leading edge, and the points on the upper and lower surfaces, given in columns two and three, are laid out vertically above the chord line at the corresponding stations. By connecting the points thus found we have the curve of the airfoil.

In laying out an airfoil, great care should be taken to get it as accurate as possible. If dimensions are not followed closely, the resultant airfoil will have an entirely

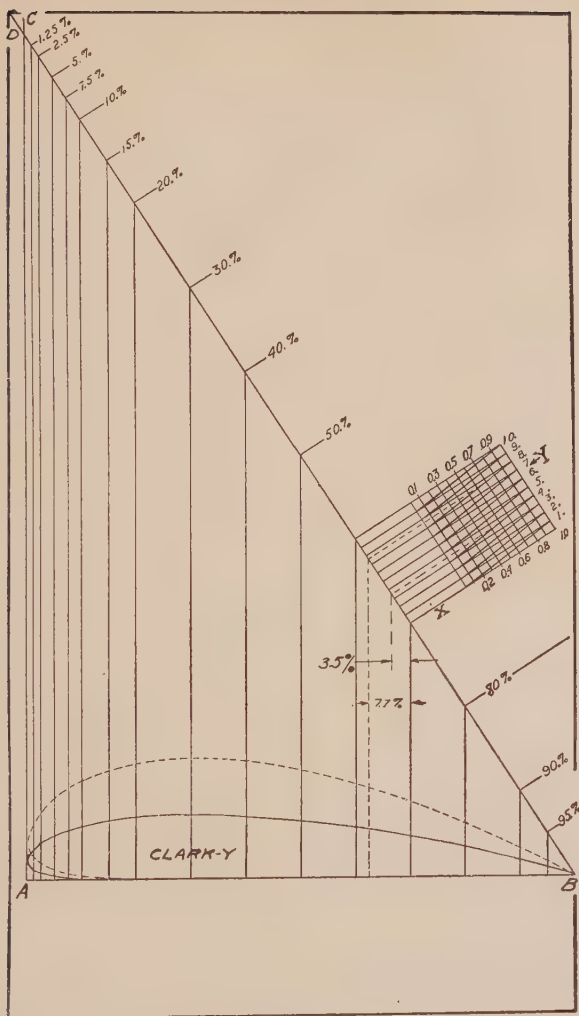
N.A.C.A.



different performance from the original one. If one can obtain the use of a vernier height gage and an angle plate, very accurate work can be done. For models it is the custom first to lay out a template of thin brass, to be used in forming the ribs of the wing. The template may be checked at each station by measuring with micrometers.

Drawing No. 3 shows a simple method of laying out an airfoil section that does away with all the calculations involved in the method described above. This new method may not be quite as accurate as the first, but because of the saving in time, it is recommended for all ordinary model work. It is quite necessary in laying out an airfoil by this method, that your pencil, if it is to be laid out on paper, or your scribe, if on sheet metal, be kept sharp. Lines must be as fine as possible to avoid inaccuracy.

The first step is to select your chord length AB . This may be any desired length. At point A , draw line AC perpendicular to line AB . Next line BD is to be drawn, whose length is 100 times any given unit, from point B to line AC . If the unit chosen is $1/8''$ line, BD would be $100 \times 1/8 = 12\ 1/2''$ in length. If the unit chosen is $1/16$, the length of line BD would be $6\ 1/4''$. Line BD could be any length as long as it intersects line AD , but by assigning it a 100-unit length, we simplify the dividing of the line into a given number of stations. To find the point D on line AC , where line BD intersects line AC , set your dividers to the required length of BD and with B as a vertex, scribe an arc whose radius is equal to BD so that it intersects AC at D .



Now, on line *BC* lay off your stations as shown in the drawings. If you have chosen $1/8''$ for your unit, the first two divisions will be $1/8''$ long, the next three $1/4''$ long, the next two $1/2''$, and the balance $1''$, except for the last two, which are $1/2''$. The length of each division is given in per cent of the line *BD* on the drawing. These divisions correspond to the stations used in laying out airfoils.

Now, from each one of these stations, drop a line perpendicular to *AB*. This will divide the chord line *AB* into the required number of stations.

On the line *BD*, divide one of the large ten per cent divisions into ten equal parts. Each one of these divisions will then be equal to one per cent or $1/100$ of the line *BD*. At these points, draw eleven lines perpendicular to the line *BD*. See drawing. If the depth of the section is greater than ten per cent of the chord, an additional line must be projected from the next lower station. The drawing shows the perpendicular drawn at the eighty per cent division. This permits us to get the percentages over ten per cent by measuring from this line instead of line *X*. The drawing shows two airfoil sections, the thin one, the Clark *Y*, has a maximum depth equal to 11.70 per cent of the chord.

Now lay off on line *X*, ten equal divisions of any convenient length. Draw eleven lines perpendicular to *X* and parallel to *BD*, through these points as shown in the drawing. From the lower left-hand corners of each of the divisions between the lines parallel to *X*, draw the diagonals, as shown in the drawings, to the upper right-hand corner. This completes the scale.

Remember that the Y scale is equal to ten per cent of the line BD and each division is equal to one per cent. Now let us locate part of the stations of the Clark Y . Study drawing No. 2. In the upper left-hand corner we have the table of ordinates given in per cent of chord. The first station for the upper surface is given as 3.5 per cent. Now we know that the units on the Y scale are each equal to $1/100$ or one per cent of the chord. Then 3.5 per cent will be equal to $3\frac{1}{2}$ of these divisions. If on the X scale, we measure along the Y line marked .05 from the line X , we will find that the diagonal drawn through the fourth division crosses this line at exactly $3\frac{1}{2}$ spaces up from X . Therefore, to get the distance that the upper surface of the Clark Y is from the reference line at station one, all we have to do is to project this point to line BD and then down toward AB . The drawing shows the point projected. The distance between the arrows can now be transferred with your dividers to station one on line AB . The drawing also shows another point projected which is 7.7 per cent of the chord. By using the diagonal system we can divide each of the one per cent divisions into tenths.

Now let's take station 2. This is given as 5.45 per cent. We know that the height is five full spaces plus not quite one half space. If it were 5.5, we should measure up the .05 line on the X scale, and if it were 5.4, we should measure up the .04 line. Since it is halfway between these points, we can project a point halfway between the .04 and the .05 line on the diagonal in the sixth space.

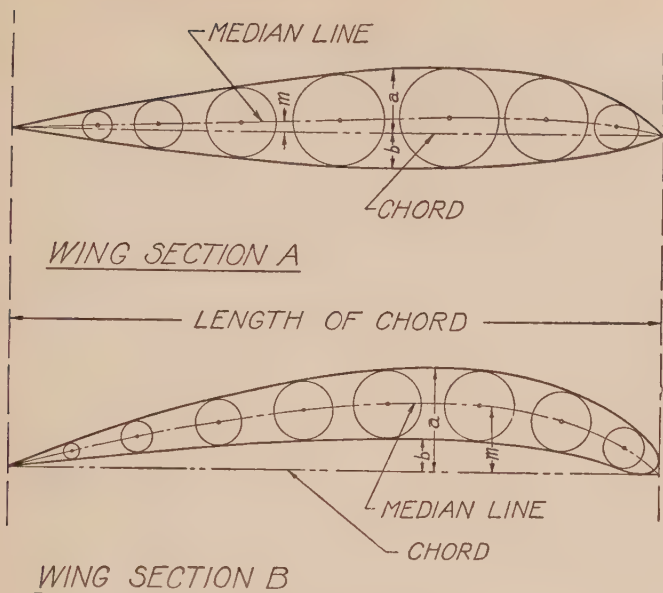
Next station 3 is 6.5 per cent. We measure along the

line marked .05 on the X scale from the line X to the point where it is crossed by the diagonal in the seventh space. The point is projected as before and distances transferred to the third station on line AB .

When you have a scale neatly made, you can use it indefinitely for laying out any number of airfoil sections by retaining the line BD and the scale. By tacking this scale to your drawing-board and drawing in the line AB equal to the new chord and AC perpendicular to AB on your new drawing, you can make use of your scale for any size chord.

The table giving the characteristics of airfoils is a reproduction of reports sent out by the National Advisory Committee for Aeronautics. These reports are printed and sent out by the Government Printing Office. Most of the reports may be had by sending ten cents for each report to the Superintendent of Documents, Government Printing Office, Washington, D.C. A list of reports prepared by the N.A.C.A. may be had by writing to the above address for them.

Drawing 4 shows the dimensions of typical airfoil sections exaggerated to bring out the details. The chord is the line that joins the leading and trailing edges. These points can be defined as the two points in the section that are farthest apart. The leading edge is often spoken of as the entering edge and is the foremost portion of the wing. The median line may be determined by joining the centers of circles inscribed in the section so that they will be tangent to the upper and lower surfaces. The distance a shows the maximum amount of upper camber and b the

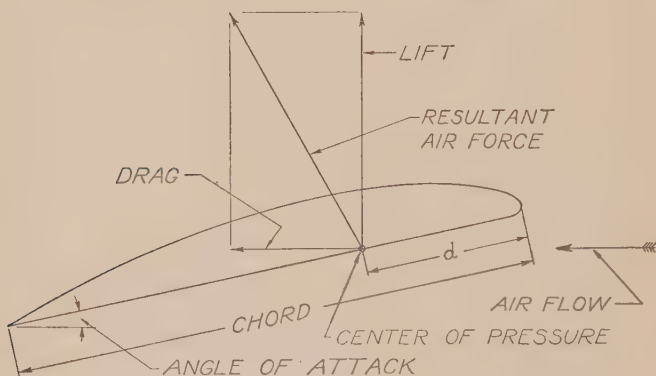


NO. 4. AIRFOIL DIMENSIONS

maximum amount of lower camber. M shows the maximum camber of median line. Tests of airfoils seem to show that the lift of an airfoil increases with the amount of camber given the median line. Of course other characteristics enter in and have to be taken into consideration when the selection of an airfoil is to be decided on.

An airfoil, or wing section, when held in the wind is acted on by two forces, lift and drag. These forces act on the section at right angles to each other. Lift always acts perpendicular to the air flow and drag parallel with it. Drawing 5 shows a graphic representation of these two

forces as they act on an airfoil. The perpendicular arrow represents the lift, and the horizontal, the drag. In an efficient section the lift will always be greater than the drag. If a parallelogram is completed with the two arrows forming two of the adjacent sides, its diagonal will be equal to the combined forces and also point in the direction that they tend to move the airfoil. This line is the vector and is called the resultant of forces.



NO. 5

Just why the airfoil will tend to move in the direction of the resultant rather than in one of the other two directions may be explained as follows: Suppose that, instead of two lines, the arrows representing force and drag were represented by two ropes. Now the drawing shows the length of the lift as twice that of the drag. Let us suppose that the rope representing lift is exerting ten pounds pull directly up while the rope representing drag is exerting a horizontal pull equal to five pounds. Under these condi-

tions the airfoil would not move straight up or back, but in the direction of the resultant, and the pull in this direction would be 11.18 pounds.

The drawing shows the two lines of force intersecting at a point known as the center of pressure. Under actual conditions the lift is not centered at one point, but is distributed along both the upper and lower surfaces.

If we find a point along the chord where these forces will just balance, we have located the center of pressure. If we were to consider only the lift, we could compare it to a teeter-totter with the forces acting down instead of up. The fulcrum or center support, when the teeter-totter is in balance, would represent the center of pressure. This must be moved backward or forward to maintain the balance as the weights change. The center of pressure of an airfoil is located by giving the per cent of chord from the leading edge. In Drawing 4 the position of the center pressure would be $d/Chord$.

The angle that the chord of the airfoil makes with the air flow is known as the angle of attack. As this angle changes, the amount of the lift and drag also changes. By careful experiments in the wind tunnel the amount of this change for all the angles of attack, from negative 12° to positive 22° , is found. This change is expressed by a number known as the coefficient. For those who are not familiar with this term, it may be defined as the number or symbol used as a multiplier to express the amount of change under certain conditions. The coefficient usually is placed before the other symbol. In mathematics, when two symbols, a symbol and a number, or a combination

of symbols are placed together, multiplication is indicated. Example: $6x$ means 6 times x and AV means A times V .

Lift is also affected by the area of the airfoil and the velocity at which it moves. Tests show that the lift of an airfoil may be expressed by the formula

$$\text{Lift} = A \text{ coefficient} \times \text{Area} \times \text{Velocity}^2$$

Then, if one knows the coefficient of lift at any given angle of attack, the amount of lift may be calculated for any given speed. It is important to remember that the velocity is squared in this formula. For example, let us suppose that the lift of a wing at a given angle of attack is fifty pounds. Now, if we double the speed, we have increased the lift to two hundred pounds or four times. Now if we triple the first velocity, we increase the lift nine times.

The coefficients for lift and drag of airfoils are given in the reports mentioned earlier in the chapter. Space does not permit a thorough explanation of these reports, but one should know at least what the various curves represent. If we turn to the N.A.C.A. reports, Drawing 2, we see in the report of the Clark Y that the various curves are designated by letters. The coefficient for lift is termed C_L and that for drag C_D . This system is part of the Absolute System, which is used in all N.A.C.A. reports.

There are four systems of units expressing lift and drag coefficients. These are the German, Absolute, Engineering, and the British. The Germans were the first to use the 'impact pressure' in the equation, the British use

mass density. The quantity (one half mass density of air $\times$ velocity ²) is known as the impact pressure per unit of area.

The Engineering system is used by almost all engineers in the United States for design work. The Absolute system is used by the N.A.C.A., as it introduces mass density into the formula, thus rendering the coefficients non-dimensional. The formula becomes independent of the system of units used, provided it is consistent. The German system is like the N.A.C.A., except that the coefficients are 100 times greater. This permits them to express the coefficients in whole numbers or large decimals. The British coefficients are one half the value of the corresponding coefficients in the Absolute system. The coefficients of the Engineering system are .00255 times the Absolute coefficients. Keeping these values in mind, it becomes quite simple to convert the coefficients of one system to the coefficients of the other.

Each system uses a different symbol to designate the forces acting on the airfoil. The lift and drag formulas are shown below for three of these systems:

	<i>Lift</i>	<i>Drag</i>
Engineering—	$Lift = K_y A V^2$	$D = K_x A V^2$
N.A.C.A. —	$Lift = C_L \times 1/2 \rho A V^2$	$D = C_d 1/2 \rho A V^2$
British —	$Lift = L_c \rho A V^2$	$D = D_c \rho A V^2$
$\rho =$ Mass density of the air		

In the Engineering System, lift and drag are given in pounds, the area in square feet, and the velocity in miles per hour. The absolute system gives the lift and drag in

pounds or grams, density of air in slugs per cubic foot, or dynes per cubic meter; the area in square feet or square meters, and velocities in feet or meters per second.

The angle of attack is shown at the foot of the table, while the lift and drag coefficients are given at the right-hand side. Now we can find the lift or drag coefficient for any angle of attack by reading the coefficients opposite the points of intersection of the curves with the lines showing the angles of attack. Example: The lift coefficient for positive 2° is .55 and the drag coefficient for the same angle is .03. At this angle, the lift is slightly over eighteen times as great as the drag.

So far we have not made any attempt to explain just why an airfoil gives lift or what causes drag. The explanation of lift which is most often given is that a vacuum is set up on the upper wing surface just behind the point of maximum camber which sucks the wing upward. It is highly doubtful if there is actually a vacuum, but it has been proved that there is an area of low or negative pressure along the upper surface which would have the same effect. It has also been demonstrated that there are areas of positive or high pressure along the lower surface. We know also that as the air flows from the wing it is deflected downward and that the force that deflects or forces the air down has the opposite effect on the wing. This action on the wing is known as lift.

Wind tunnel tests, with special manometers to measure the pressure on the airfoils, show that the greater part of the lift is distributed along the upper surface. The lift at high angles of attack, between twelve and twenty-

four degrees, is from four to five times as great on the upper surface as that of the lower, and at angles of attack smaller than this is almost entirely distributed on the upper surface.

Drag is the resistance which the airfoil offers in passing through the air. Air is said to have viscosity; that is, it has a tendency to stick or adhere to any object being drawn through it. If one were to draw an object through syrup it has the same effect. Of course the viscosity of air is nowhere near as great as that of syrup, but it is present and has the same effect, only to a lesser degree.

Most airfoils have a minimum drag at angles of attack near 0° . The coefficient of drag increases as the square of the lift coefficient as long as the lift coefficient increases in proportion to the angle of attack. After this it increases very rapidly.

The L/D or the lift drag ratio as it is known, is the lift divided by the drag. The L/D is very important in selecting an airfoil. At the angle of attack of zero lift, the L/D equals zero. As the angle increases, the L/D increases very rapidly, reaching its maximum at about two to three degrees. This is the most efficient angle at which the airfoil can fly, and is the angle of incidence given to most wings. The angle of incidence is the acute angle between the chord of the wing and the thrust line or propeller shaft. The maximum L/D in the Clark Y is about positive 1° (Drawing 2).

The last curve shown on the report is the center of pressure travel. This is very important in selecting an airfoil, as it affects the stability of the entire plane. This

is easily explained when we think of the lift as a force, not distributed evenly along the airfoil, but acting at one point. If this point moves up close to the leading edge, the nose of the airfoil will tend to rise, thus increasing the angle of attack. When the angle of attack increases, we get an entirely different set of lift and drag coefficients and the center of pressure moves still farther forward. In an airfoil this will continue until the airfoil turns completely over. This is known as unstable C.P. travel. The center of pressure seldom approaches the leading edge closer than thirty per cent of the chord from the leading edge, for angles greater than zero lift. As a rule this occurs at or slightly under the angle of maximum lift. This is known as the maximum forward position of the center of pressure.

The report shows the per cent of chord from the leading edge on the left-hand side when the center of pressure travel is plotted against the angle of attack. The center of pressure curve for the Clark *Y* shows that at an angle of attack of negative 4° the center of pressure falls at a point about ninety-seven per cent of the chord from the leading edge, or almost on the trailing edge. As the angle of attack increases, the C.P. moves forward rapidly until at 0° angle of attack the C.P. falls approximately on a point only forty-three per cent of the chord from the leading edge. From this point the curve begins to flatten out and reaches its maximum forward position at an angle of positive 14° .

In selecting an airfoil where stability is desired, one should select an airfoil with a flat C.P. curve between the

angles of attack at which the plane is expected to fly. In the Clark *Y* at angles of attack between 0° and 16° the C.P. moves forward about 13 per cent of the chord.

Unlike an airfoil the C.P. for a flat wing, or flat plate, does not move forward as the angle of attack increases, but moves back toward the trailing edge. As the angle increases, the C.P. moves to the rear, having a restoring moment on the plate tending to restore it to its original position. If the angle of the attack decreases, the C.P. moves forward, tending to increase the angle of attack and thus restore it. This type of C.P. is known as a stable center of pressure travel. By using flat wings, advantage is taken of this fact in some indoor models.

A stable C.P. travel can be given an airfoil by giving the median line a negative curve near the trailing edge or by designing the airfoil so that the position of the maximum ordinate or thickness is well up toward the leading edge. In both cases, because of other characteristics, these airfoils become very inefficient.

The effect on their performance of changing airfoil dimensions may be summed up as follows:

1. The position of the maximum camber should lie between twenty-five and thirty-three per cent of the chord from the leading edge to obtain the best lift drag ratio, L/D .

2. By increasing the amount of the upper camber, the lower camber remaining constant, we obtain an airfoil with a high lift coefficient. The highest L/D is given by airfoils having an upper camber of from .05 to .12 per cent of the chord. Airfoils having small upper cambers

have the lowest drag coefficients. The C.P. curve is affected very little by increasing the upper camber, but the maximum forward position falls farther back on thick airfoils.

3. By adding lower camber to an airfoil having an upper camber of about 12 per cent of the chord gives lower lift coefficients. The L/D increases as the amount of lower camber increases as the drag coefficient decreases.

Wind tunnel tests have shown that thick airfoils may be compared favorably to the thin sections as far as efficiency is concerned. They have a low drag at small angles of attack and give high lift and large values for L/D at increased angles of attack. The thick airfoil has the advantage that all the bracing may be contained internally, permitting a considerable reduction in parasite resistance.

CHAPTER IV

WING DESIGN

FROM the foregoing chapter on airfoils, we have learned that the shape of the airfoil is very important in the performance of the airplane. The plan-form or finished shape of the wing is also very important, the shape of the wing tips, the ratio of the spars, lateral dimension, to the chord, and the method of bracing all have to be taken into consideration in the design of the wing. As in the case of the airfoil the resultant of the lift and drag force is known as the center of pressure. In studying the wing, we are interested in its lateral travel. Manometer tests show that this moves toward the tip of the wing at high angles of attack. In building a large ship, the designer should know just how much of a load any part of the wing will be subject to at any angle of attack.

One of the most important factors to be considered in the design of the wing is its aspect ratio. This is the ratio of the span to the chord. If the wing has other than rectangular plan-forms, the ratio will be the square of the span to the area. Wind tunnel tests show that the high aspect ratio gives a slightly higher lift coefficient, while the burble point, or point of maximum lift, falls at slightly smaller angles of attack. The L/D increases considerably with the aspect ratio. This is very important

in designing the wing. Designers seldom use an aspect ratio of less than 4.5 or more than 8.5. There are three reasons for this:

a. As the aspect ratio increases, the thickness or depth of the spars will decrease in proportion to the area. In the high aspect ratio the internal structure is very weak, and external bracing must be used to obtain the necessary strength.

b. If the aspect ratio increases, the area of the tail must also be increased to give lateral control.

c. A high aspect ratio means a large span. The housing of planes with large wing span becomes a difficulty that is expensive to overcome.

Wings are often tapered in plan-form because of definite advantages that have been proved occur with this type of wing. Among these advantages are a higher L/D , a higher maximum lift coefficient, and a better climbing ability at high angles of attack. The chief objection to the tapered wing is the increased cost of construction, as each rib must be made from a separate jig.

There are three methods of tapering a wing:

a. Tapering in thickness only. In this case the chord remains the same length at both the tip and root section (center of wing) of the wing.

b. Tapering in chord only. In this case the chord only is changed; the section, because the ordinates are given in per cent of the chord, remains the same throughout the span of the wing.

c. Tapering in chord and thickness. In this case we have a combination of *a* and *b*. Actual tests seem to

show that such a wing is slightly superior to the other two classes. Wings tapered in plan form so that the chord at the tip is equal to approximately fifty per cent of the chord at the root, with a slight taper in thickness (never over twenty-five per cent), seem to give the best results.

When tapering a wing in thickness, a definite percentage is decided upon and the ordinates are reduced by that amount, when laying out the section. A wing is not considered as being tapered in thickness, even though the chord at the tip is reduced, provided the section is not changed.

The tapered wing lends itself to lighter structure and also permits added strength where it is most needed. A complete report on the effect of tapered airfoils may be obtained in N.A.C.A., Report No. 152.

The shape of the wing tip also affects the performance of the wing. Tests show that the negative rake (a curved tip on a wing whose leading edge is longer than the trailing edge) is more efficient. The elliptical follows very closely and because of its appearance is favored by designers.

Airplanes designed to carry heavy loads must have correspondingly large wing area. In a monoplane type of wing, this sometimes is objectionable because of the great span required. By mounting the wings one above the other, we can overcome this to a great extent. Such an airplane is called a biplane. When three wings are used, it is called a triplane. In extremely large monoplanes, the wing structure must be very deep to allow

proper bracing unless external bracing is resorted to. As this cuts down the effectiveness of the wing, it is avoided whenever possible. The very nature of the structure of the biplane allows ease of bracing, and permits the use of thin airfoils increasing the speed of the plane.

There are many objections to the use of the biplane, and the designer is always looking for a means to overcome these. We know that the airfoil obtains its lift by deflecting the air downward and that the greatest lift is given to the upper wing near the point of maximum camber. It is easy to see that the air, being deflected downward (down wash) from the upper wing, will interfere with the maximum lift or low pressure area above the lower wing. In order to avoid this, the wings are set one ahead of the other. This is called stagger. The stagger is said to be positive when the upper wing is ahead of the lower and negative when it is behind the lower. Staggering the wing increases the efficiency of the combination, as the high lift area of the lower wing occurs behind that of the upper wing rather than directly under it. The distance between the wings is known as the gap. It is expressed by the ratio of the perpendicular distance between the chords to the chord. The combining of airfoils cuts down the efficiency of the entire wing over that which would be obtained in a monoplane. Because of the necessity of obtaining proper stability by the setting of the wings, thus controlling the center of gravity and because of the importance of unobstructed vision, the designer has to use his judgment in the placing of the wings.

It is often desirable to improve the stability of a biplane or triplane by setting the wings of the combination at different angles of attack. This angular difference in the angles of attack is known as 'decalage.' In a biplane it is said to be positive when the lower wing has the greater angle of attack. In a triplane the decalage would have to be given separately, using the upper wing as a reference.

CHAPTER V

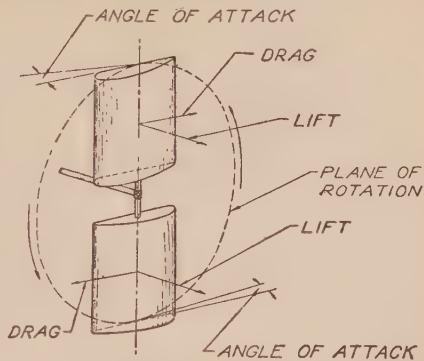
PROPELLERS

A BOAT is driven by means of a propeller or screw revolving in the water. The propeller is driven by the torque or force applied by the engine to the shaft, and literally it screws itself forward or backward. The case of the airplane is very similar. It, too, is driven by a propeller or air screw. All the early designs of air screws were copies of the marine screw. These, because of the different conditions that have to be met by a screw working in air, were never very successful. In 1907 a Polish scientist named Drzewiecki proposed what is known as the 'blade element' theory for the design of air screws. This theory, with a few changes, is the one accepted as the most satisfactory to-day.

If two airfoils, exactly alike, are mounted on a shaft, as shown in the diagram (Drawing 6), and the shaft revolved, the airfoil will be moving relative to the air. This being the case, we have also both lift and drag analogous to a moving airfoil. Study the drawing carefully; notice that the airfoils are set at a slight angle of attack relatively to the plane in which they revolve. The lift will be horizontal and parallel to the shaft, as the airfoils are revolving in a vertical plane. The twisting motion or force applied by the engine to the shaft is called torque, and in the airplane it is this force that drives the propeller.

As explained in the chapter on airfoils, lift is obtained

because air is set in motion and deflected downward. In this case the lift is obtained because the revolving airfoils set in motion and deflected backward a cylinder of air equal to the length (diameter) of the propeller. In the case of the propeller the lift is called thrust. The propeller is, therefore, an apparatus for transforming the power or torque



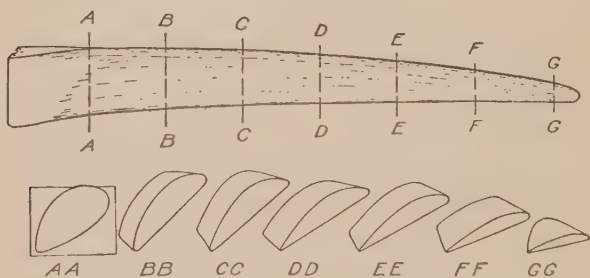
NO. 6. THEORY OF PROPELLER

applied to the propeller shaft into thrust which is the force that pulls the airplane through the air.

As the airfoils shown (Drawing 6) revolve, the outer ends move much faster than the parts near the center, as the circumference of the circle in which they travel is much greater than the circles at the hub. The faster-moving parts give more lift while the center parts lag behind; taken as a whole the apparatus is very inefficient. We know that the lift of an airfoil varies as the angle of attack. Now if we can twist the airfoils so that as we near the center the elements will be given a proportionally increased angle of attack, we can equalize the thrust of all the elements along the entire length of the blade even though they are revolving at different speeds.

In a propeller each airfoil is known as a blade. In the

Drzewiecki theory every element of the blade is investigated separately and the amount of twist is calculated by mathematics. Not only is it necessary to give the center sections a greater angle of attack, but, because of the increased strains placed on this part of the propeller, they must be made much thicker. Study the drawing of the cross-sections of a propeller blade (No. 7). This in-



NO. 7. PROPELLER BLADE WITH SECTIONS

creased strain on the center section is caused by the stresses due to bending moments, centrifugal force, and in the fact that all the lift of the tip sections must be borne by the center sections. In a large propeller the center sections are made so thick that they give practically no lift at all. This is also true in the models where the angle of attack is so great that the burble point has been exceeded and the hub becomes almost a flat plate normal (perpendicular) to the plane in which it revolves. In the real plane the flow of air at the center is interfered with by the fuselage. In some airplanes where the fuselage or cowlings is allowed to end rather abruptly,

or when large-diameter air-cooled engines are used, this interference, called blanketing, becomes serious, as it cuts down the effectiveness of the propeller and increases the cost of operation of the entire plane. Excessive blanketing must be carefully guarded against in the designing of a large plane.

Similar to an airfoil, the propeller has a leading edge and trailing edge. The aspect ratio of a propeller is equal to one half the diameter divided by the maximum blade width: that is, a propeller with a diameter of eight feet and a maximum blade width of eight inches would have an aspect ratio of 48 to 8 or 6 to 1.

The distance that a nut moves forward on a bolt, in one revolution, is known as the pitch. If we could devise some means by which a propeller could screw into solid guides to prevent slipping, the distance it would move forward in one revolution would be equal to the pitch. This is called the geometrical pitch.

The geometrical pitch is usually stamped on the hub of the propeller and as a rule is calculated for an element of the blade two thirds of the radius from the center of the hub. The ratio of the geometrical pitch to the diameter of the propeller is known as the pitch ratio.

Turning in air, a propeller because of slippage will not move forward a distance equal to the geometrical pitch. The actual distance that it moves forward in one revolution is known as the effective pitch. The difference between the geometrical pitch and the effective pitch is known as the slip per revolution. This slipping is a measure of the efficiency of the propeller. The efficiency of the

propeller increases as the effective pitch approaches to the geometrical pitch. The thrust of the propeller depends on the amount of air that is set in motion; it follows, therefore, that the larger the diameter of the propeller the greater will be the mass of air that is set in motion. As the mass of air that is handled for a given thrust increases, the amount of slip decreases.

The speed of the propeller is another factor that must be considered in checking its efficiency. The tip speed is always taken when the speed is given. When the tip speeds exceeds 850 feet per second, the efficiency drops very rapidly. In the case of the model with the rubber-driven propeller we do not have to worry about excessive speeds. Since the efficiency of the propeller depends on the mass of air that can be handled for a given thrust, it follows that the larger the diameter the more efficient will be the propeller. In constructing models we have the advantage of the large ships, as we can design propellers with a diameter equal to one half the span of the wing. Not only does the large propeller handle a greater mass of air, but it also increases the duration of the plane as it slows up the rubber motor.

For model work, the pitch of a propeller may be determined from the block from which it is carved by use of the formula —

$$\text{Pitch} = \frac{\pi D}{W} \times T$$

When $\pi = 3.1416$

D = diameter of propeller or length of block

W = width of block

T = thickness of block

Example: Given a block $11/16'' \times 1\frac{1}{4}'' \times 10''$, find the pitch of a propeller carved from this block.

$$D = 10''$$

$$W = 1\frac{1}{4}'' = 1.250''$$

$$T = 11/16 = .687''$$

$$P = \frac{10 \times 3.1416}{1.250} \times .687 = 17.243''$$

Then the pitch equals 17.243, or for practical purposes it could be called 17.25.

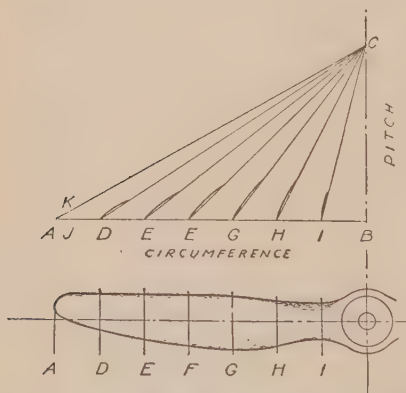
The effective pitch of an indoor endurance model was determined recently in a series of tests by the author. The motor (a double strand of $1/8''$ -30 rubber 15'' long) was given five hundred turns and the propeller allowed to unwind for thirty seconds to determine just how fast the rubber unwound. This was done a number of times and the average found. An interesting fact about the test was the slight amount of variation found in each test. At no time did the number of turns vary more than two. When the average number of turns that the rubber would unwind in thirty seconds was determined, the plane was flown with five hundred turns given the motor as in the previous tests. The distance that the plane traveled in thirty seconds was calculated by measuring the diameter of the circle and timing the plane while it made four complete turns. Then, by dividing the distance traveled by the number of turns the propeller makes in the same length of time, the effective pitch or distance traveled in one revolution is obtained.

In all the tests the best results were obtained using an

indoor endurance plane. The weight of each part was as follows:

NAME OF PART	WEIGHT OF PART
11" propeller 18" geometrical pitch	.019 ounce
15" fuselage assembled	.042
19" wing with clips	.046
2 strands rubber motor	<u>.054</u>
Weight of model	.161

In five separate tests with this model the effective pitch was calculated as 17.9. This is only one tenth variation from the geometrical pitch, or the slip in this case is almost negligible.



NO. 8. GRAPHIC METHOD USED TO DETERMINE ANGLE OF BLADE FOR A GIVEN PITCH AND DIAMETER

A graphic method used to determine the angle of attack for any element on the blade of a propeller is shown in Drawing 8. The line AB is laid off equal to the $D\pi$ or the circumference swept by the tip of the propeller. Line BC is laid off equal to the pitch and drawn at

right angles to AB . Now the line AB may be divided into as many equal divisions as the points to be determined on the blade. By connecting these points — seven are shown in the drawing — the angles formed by

these lines with the line AB are the angles of attack that should be given to the elements at the corresponding points on the blade of the propeller.

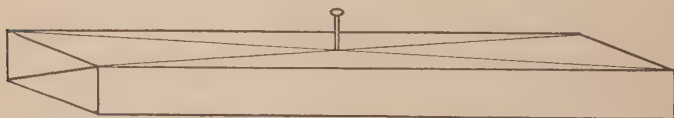
The design of the model propeller can be simplified by using the block method to figure the pitch. If one has a given diameter in mind, he can easily determine the width and thickness of his block by using the graphic method shown above to determine the angle at the tip. The desired width of the blade AK is laid out on AC , and KJ is drawn perpendicular to AB . Then AJ is equal to the width of the block and KJ is equal to the thickness. When the propeller to be drawn is large, the diagram may be laid out smaller, but must be to a scale, such as one fourth or one eighth size.

There are a number of methods used in carving propellers for models. Each has its merits. The type shown below has been used on more record-breaking models than any other, and have proved in this way their effectiveness. These are called the Langley because it is the type used by Professor Langley on his planes.

A few years ago almost all the propellers used on models were carved either from white pine, birch, or white wood. This was before the advent of balsa wood, and the construction of the entire model was proportionally heavy. This type of propeller is unsatisfactory when the rest of the model is constructed with balsa, as it becomes nose-heavy. A light medium-hard grade of balsa is recommended for propellers. One should be careful to see that the wood is not cross-grained and that it is free from all checks. Some model-builders prefer to use extremely

soft wood, obtaining added strength by giving the finished propellers a coat of banana oil. For flying model airplanes the propeller blades are carved to form a thin flat cambered surface rather than the thick airfoil type used on the large plane. This is necessary in order to cut down weight, as the thick propeller would be much too heavy for the light scientific models now in use. Even if this were not the case, the weight saved is worth more in contributing to duration than the increased lift would be, due to the thicker blade.

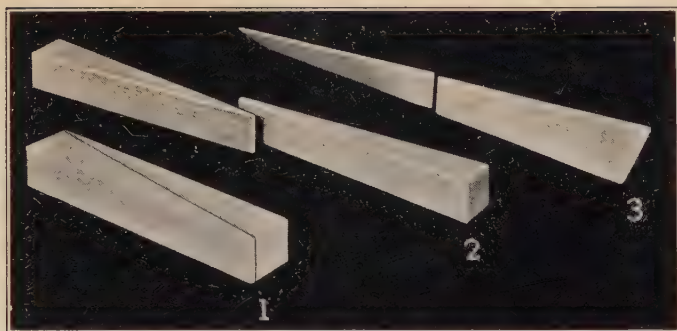
Drawing 9 shows the first step in carving the propeller. The block should be carefully trued up to the required size and well sanded. Diagonals are laid out on the wide



NO. 9. FIRST STAGE PROPELLER CARVING

faces and on the ends as shown. Notice that these end diagonals are drawn in opposite directions. At the intersection of the diagonals, on the flat faces, the hole for the propeller shaft is drilled. This may be done by pushing a pin through the block. Extreme care must be taken to keep the hole straight and at right angles to the faces of the propeller.

Drawing 10 shows the next step. Notice how the block has been carved along the diagonals except at the center. This section should be left at least $1/8''$ thick until the blades are nearly finished.



THE SECOND STAGE OF PROPELLER CARVING

No. 1 shows block cut along diagonal to make the two blocks shown in No. 2. No. 3 shows semi-finished matched propeller blades.



FIVE STAGES OF PROPELLER CARVING USING BLOCK METHOD



PROPELLER PLANFORMS

1. Mott propeller. 2. Abgarian mystery ship propeller

The photograph shows another method of getting the second stage of propeller carving. In this case a block



NO. 10. SECOND STAGE PROPELLER CARVING

one half the diameter of the finished propeller is used. (See view No. 1.) This is cut across on one of the diagonals as shown in the photograph to form two blocks. These two blocks can be butt-jointed or half-lapped to form the same shape as shown in Drawing 10.

The advantage of this method is that both blades of the propeller will have exactly uniform balsa both as to texture and weight. This makes it easier to balance the finished propeller. A 10'' or 12'' block of balsa wood will often vary a great deal in hardness and weight. When the blades are cut from a block one half this length, this variation is reduced to a minimum. The upper picture (No. 3) shows two blades of Wanner semi-finished propeller. This shows two blades carved by a special machine from a block in such a manner that they are perfectly matched. This is possible as they are sliced from the blank, each one being from the adjoining or parallel piece. Matched propellers of this nature have a truer pitch than can be given by hand carving and reduce the time of finishing a propeller to less than one fifth of the time formerly required.

The face corresponding to the lower surface of an airfoil when used as a propeller is carved first. Notice that it

is not flat, but slightly concave or hollowed out. This is called 'camber,' and has the same effect as camber on an airfoil.

The photograph of the five stages of propeller carving show the steps in their order. The concave side of the propeller is completely finished, except for finish sandpapering before the convex side is started. This gives your blade extra strength and so lessens the chance of breaking while finishing. It is also easier to cut the convex side to follow the concave than to finish the curve after the blade has been roughed out on both sides.

This camber can be given by sanding carefully after the face is finished flat with the knife. The amount of the curvature may be checked by the use of a steel rule laid across the blade. It should not exceed $1/32''$. When this face has been completed, the opposite one may be finished by carving until the blades are about $1/16''$ thick. The convex side is finished to correspond with the finished side by sanding. (No. 4.)

When the blades are finished, they should be not more than $1/32''$ thick, gradually tapering to $1/16''$ at the hub. As we know, the center section of the propeller is very inefficient, and, as we are always watching for ways to eliminate weight, we cut out as much of this section as possible. This is done by cutting from the trailing edge a flat *V* as shown in No. 5.

The tips can now be rounded, the edges well sanded, and the propeller is ready for the shaft. This is made from music wire and when passed through the hub, is bent in the shape of a square 'U.' The short end of the

'U' is then embedded in the propeller and the entire hub painted with cement to prevent breaking.

The photograph of the two propellers illustrates the two most popular shapes for finished propellers. No. 1 is the type of propeller used by Albert Mott in his prize-winning models. Notice that it is much shorter than No. 2, but wider. This type of propeller is often spoken of as a butter ladle because of its width. No. 2 is a photograph of the propeller Aram Abgarian used on his mystery ship that won him a trip to Europe. Because of its greater diameter, it is more difficult to fly than the wider one. It is theoretically more efficient than No. 1. Both propellers have approximately the same area.

Aram carved his propeller from a block $1\frac{1}{2} \times 1\frac{1}{4} \times 12''$, and later twisted his blades to increase the pitch. He recommends a block $3\frac{3}{4} \times 1\frac{1}{4} \times 12''$ and says that he has obtained even better results than with the $1\frac{1}{2}''$ block.

A propeller is said to be a right-hand propeller when it turns in a clockwise direction when viewed from the rear of the plane. If it is turning anti-clockwise when viewed from the same position, it is said to be a left-hand propeller. An airplane is said to be a tractor airplane when the propeller is ahead of the main supporting surface, and is said to be a pusher airplane when the propeller is behind the main supporting surface.

CHAPTER VI

THE CARE OF RUBBER MOTORS

IN models as in the large airplanes the type of power plant to be used is of prime importance. The designer of a large airplane builds his ship around a motor with a known performance. The model-builder, because of his lack of knowledge of design, builds a ship and adapts his motor to it. This is not such a bad practice, as he can, without much trouble, decrease or increase his available power very easily. Of course this applies only when rubber strands are used for power. However, if one is familiar with the characteristics of rubber, a much more intelligent procedure may be followed with a corresponding increase in performance.

Many model-builders have successfully flown models powered with miniature engines. These power plants include the coil spring or clock works engine, steam engines, compressed air motors, and small gas engines. If one has the equipment and skill to construct engines of this type, they make very pretty models. The greatest source of satisfaction, however, comes in constructing them rather than in flying the finished models, as it is impossible to obtain any duration comparable to that received from rubber-driven models. This is due to the increase in weight with this type of engine over that of the rubber motor. When the weight of the motor is increased, the

construction of the entire model must be designed to stand the heavier loads, and the completed ship is proportionately increased in weight. As there are comparatively few boys that have the necessary equipment for constructing this type of power plant, and as most libraries contain a number of books on model engines, none of these will be described in this book.

More energy can be stored up in rubber than in any other known source of power, weight for weight. Because of this, the low cost, and the ease with which it can be obtained, it is very doubtful if rubber will ever be supplanted by any substitute as the favorite motive power for models.

There are many interesting characteristics of rubber with which every model-builder should be familiar, in order to get the maximum from his planes. The available information on this subject is very limited. It is to be regretted that, although many experiments have been made in the past to determine these, very little has been published. At the present time a number of clubs are conducting experiments and comparing results.

Good Para rubber can be stretched to eight times its length, and if it is released within a short period it will return to the original length. If it is kept distorted for any appreciable length of time, it will not return to its original length, but will be slightly longer when released. If rubber is stretched far beyond its elastic limit, its efficiency as a power plant falls off very rapidly in that it becomes what is called dead. This happens also when a motor is left fully wound for any length of time. The rub-

ber loses its power and is sluggish in unwinding. This is the reason that in contests the contestants refuse to wind their motors until the judges are ready to time their flight.

By a number of tests it has been determined that rubber varies in the power or torque which it develops in unwinding proportionately to the number of strands used. Just what the proportion is or what is the formula for it has not been developed. Because of the many variable factors (length and cross-section remaining the same) that affect these tests, such as the temperature, length at which it is stretched, etc., it is difficult to make all the necessary computations, but by the use of empirical formulæ we ought eventually to obtain a fairly accurate table of coefficients.

Preliminary tests seem to show that by increasing the numbers of strands by one half we increase the torque twice; by doubling the number of strands we increase the torque about three and one half times; and if we increase the number of strands three times we get almost seven times as much torque. Example: if we have a four-strand motor, giving a torque of two units, by increasing it as above we should obtain approximately the following results:

NUMBER OF STRANDS	TORQUE	TURNS
4	2	600
6	4	460
8	7	368
12	14	320

The rapid increase in torque is explained by the fact that the large diameter of the motor distorts the outer layers or coils to a much greater degree than with the smaller motor and these rapidly approach the breaking point. Although the torque increases rapidly as we increase the number of strands, the number of turns that it is possible to give the motor falls off for the same reason.

The graph on page 71 shows the results obtained in the first part of an experiment being conducted by the members of the Michigan Model Airplane Club. The object of the test was to find the variations in the breaking point of rubber under different conditions. Two-strand rubber motors of $1/8''$ -30 rubber 15 inches long were used in the tests. A number of pieces were broken each time and the average taken in order to avoid any error. A 5 to 1 ratio gear winder equipped with a counter was used in winding the rubber.

Fresh rubber was wound until it broke, stretched to 45'', 60'', 67.5'', and 75'' and the breaking points were noted. Then new rubber was wound to 500 turns while stretched to 45'' or three times its length, and allowed to unwind. This is known as prewinding. After the rubber had been prewound, the same tests were made on it as on the fresh rubber and the results noted. The tests were repeated, using rubber prewound at 800 turns and 1000 respectively. The following table shows the average breaking points for each test:

BEGINNING TO FLY

DATA SYMBOLS

P.W. — Number of turns given in prewind

D.S. — Distance stretched in test

A.B.P. — Average breaking point

TABLE 1

P.W. = 0

D.S. = 45"

D.S.	A.B.P.
30	868
45	1190
60	1243
67½	1273
75	1285

TABLE 2

P.W. = 500

D.S. = 45"

D.S.	A.B.P.
30	961
45	1212
60	1273
67½	1257
75	1232

TABLE 3

P.W. = 800

D.S. = 45"

D.S.	A.B.P.
30	1123
45	1123
60	1329
67½	1305

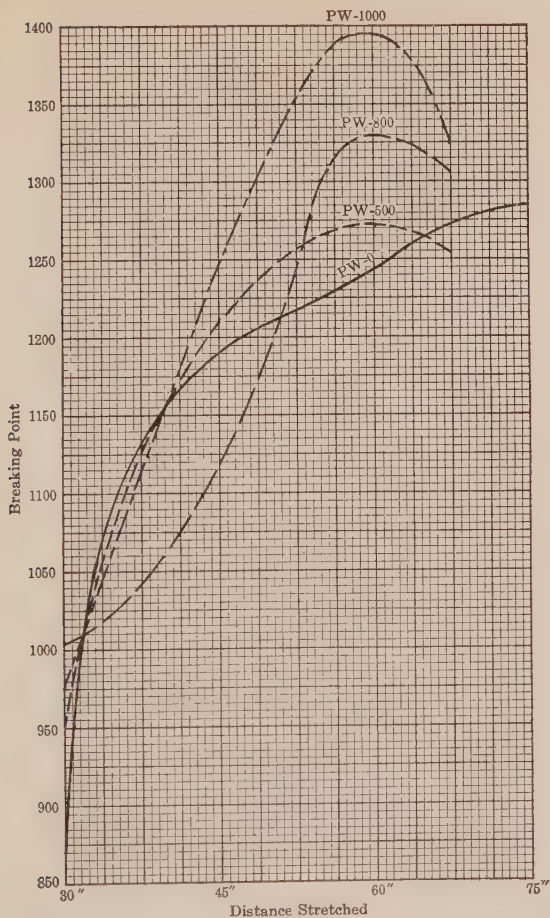
TABLE 4

P.W. = 1000

D.S. = 45"

D.S.	A.B.P.
30	976
45	1247
60	1396
67½	1322

From the above tables we can see that rubber will take more turns without breaking when stretched to approximately four times its length, and that the breaking point drops rapidly when the rubber is stretched in excess of this. The graph shows the breaking point plotted against the distance stretched. Each of the curves represents one of the tables, and the curves are labeled according to the number of turns given in the prewind. Remember that all the prewinds were given to the rubber while stretched

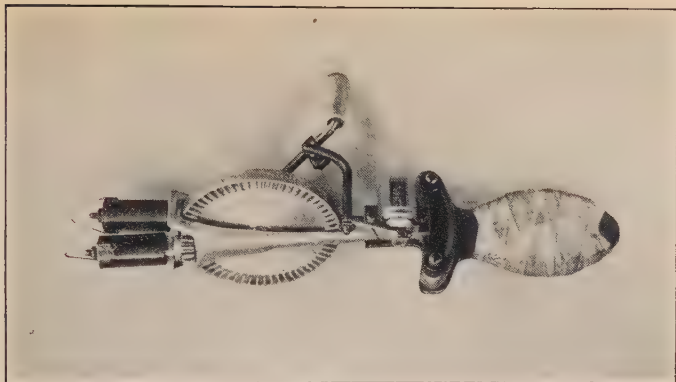


GRAPH SHOWING BREAKING POINT OF RUBBER

at 45". The curves show that the average breaking point of a 15" two-strand motor of 1/8"-30 rubber is at 1396 turns when the rubber is first prewound at 1000 turns while stretched at 45". This is an increase of 528 turns over that which can be given fresh rubber without any prewinds and stretched to twice its length. The number of turns that can be given unstretched rubber is only about two thirds of that when stretched to twice its length.

Such information is valuable to the model-builder entering duration contests. The tests shown are only a small part of the work to be done. As stated the rubber was all prewound at 45", and to get complete results the same test must be followed, stretching the rubber to different lengths for the prewind. Accurate results cannot be obtained unless a number of pieces are broken in each test and the average taken.

Of course the results of the above test cannot be taken for motors of different sizes, cross-sections, and lengths. Although the breaking points will be different, the curves will be similar. Many other factors have to be considered before the most efficient conditions for winding this size of motor can be determined. The Michigan Model Airplane Club, in order to determine the effect of stretching and prewinding on the power output, is devising a machine to measure the exact amount of power necessary to keep in the air an endurance model powered with this motor. When the power curve has been plotted, they will measure the effect and plot the power curve for rubber under the above conditions. The intersection of these



THE EGG-BEATER WINDER WITH A SPECIAL HANDLE
Notice the counter



JACK LOUGHNER, NATIONAL OUTDOOR CHAMPION
1926-27, WINDING WILLIAM CHAFFEE'S INDOOR MODEL
Notice how easily the rubber is stretched when the winder is used

curves will determine the correct condition for winding motors for these planes. A safety factor has to be allowed in using these tests of about ten per cent; that is, we should not think of giving our motor the full number of turns, but within ten per cent to ensure not breaking the rubber.

When rubber is distorted from winding, to any great extent, the strands stick together. These should be carefully separated after each flight and the rubber allowed to rest. Pure powdered talc or soapstone will help to prevent this sticking as well as help to preserve the rubber. Some model-builders use lubricants to prevent sticking by allowing the strands to slip over one another with a minimum amount of friction. A good lubricant can be made from glycerine, soft soap, and washing soda. A solution of eight parts of water, four of glycerine, and two of soft soap, and one of washing soda makes a good lubricant. The solution should be well mixed and boiled for some time. If it thickens on cooling, more water should be added and it should be reboiled. The liquid can be kept in a bottle and applied with a brush when used. The rubber should be washed in a warm solution of soda and water when being put away. Tests which have been made by model-builders using this solution show that the amount of energy that can be stored up in lubricated rubber is almost twice as much as that in unlubricated rubber.

Of course, other factors that must be considered are the weight of the lubricant, the difficulty in carrying it about to contests, and the mess that it makes of everything in

handling it. The last two reasons are not serious, and in contests, although undesirable, can be endured. Whether the additional weight is compensated for by the increase in power is the point that should decide whether one should use a lubricant or not.

Light has a very injurious effect on rubber, especially the direct rays of the sun. The author has obtained the best results in preserving rubber by keeping it in an air-tight crockery jug in an even temperature.

As stated above, rubber can be given more turns when stretched to four times its own length. In order to do this, we need to employ some mechanical means of holding the rubber while winding. The egg-beater winder shown in Drawing 11 not only serves this purpose, but, in addition, because of its five to one gears, allows much faster winding. This last is an important factor, as rubber loses its elasticity very rapidly if kept wound any length of time.

The photograph shows a completed winder made from an aluminum egg-beater with a counter attached. This counter is very useful in winding a plane, as the number of turns given the rubber can be had at a glance. In the drawing (Figure 1) is shown the completed winder without the attached counter. Figure 2 shows the blades or beaters cut off $1\frac{1}{2}$ " from the small bevel gear, except for the center shaft, which is left $\frac{5}{16}$ " longer. A $\frac{1}{8}$ "-32 thread must be cut on this shaft to a point even with the blades. Figure 3 shows a piece of $\frac{5}{16}$ " square stock $1\frac{1}{4}$ " long with a $\frac{1}{8}$ " hole drilled through the length of it. This steel block slides in between the cut-off blades,

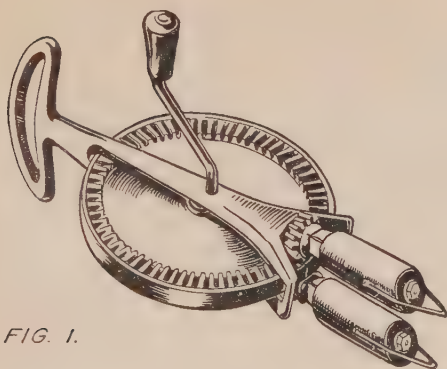


FIG. 1.

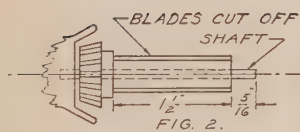


FIG. 2.

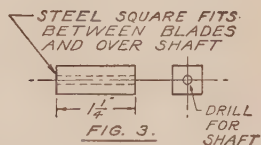


FIG. 3.

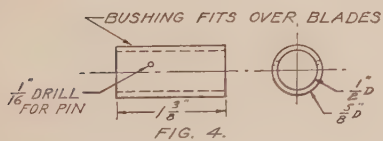


FIG. 4.

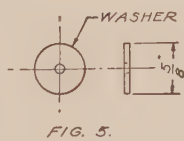


FIG. 5.



FIG. 6.

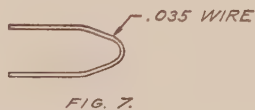


FIG. 7.

NO. II. EGG-BEATER WINDER

with the center shaft running through the hole. The cross-section shows how the block fits firmly inside the stumps of the blades. The bushing shown in Figure 4 can be cut from $5/8''$ round steel. It is made to slip tightly over the cut-off blades, as you can see from the photograph. A small washer (Figure 5) is then placed over the end, and a small hexagonal nut is attached to hold block, blades, bushing, and washer in place. Do not tighten the nut too much or the winder will be hard to turn. Now the U-shaped piece (Figure 7) is bent from .035 music wire. The photograph shows how it is soldered to the bushing.

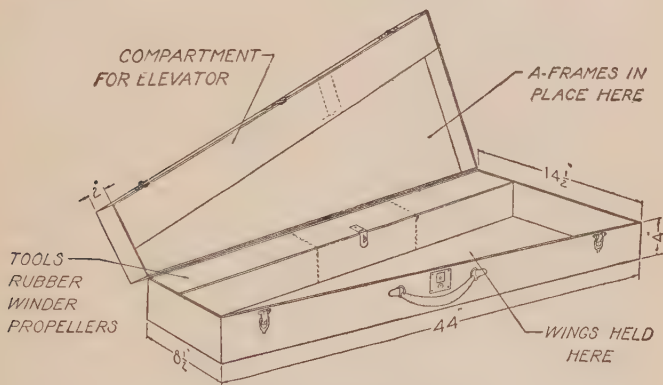
The last operation is the drilling of a $1/16''$ pin hole in the bushing. This must be done after the winder is completely assembled. The hole must be drilled to one side of the center so as to miss the shaft and yet go through the square block. A piece of $1/16''$ rod is then driven through the hole and soldered at each end to keep it from working loose. Make sure that the winder works freely, and then solder the nut to the shaft to prevent it from ever coming off.

Of course, the process is the same for both shafts, so that the two sets of blades should be cut together and the process should be followed through for the winders on both gears at the same time.

CHAPTER VII

TOOLS AND MATERIALS

EVERY model-builder should have at least two kits in which to keep his finished models when not in use as well as to provide a means of carrying them from place to place.



NO. 12. OUTDOOR BOX

Drawing 12 shows you the best type of box to build for outdoor planes. Notice that it is wider at one end than the other so that the 'A' frame of your ship will fit nicely into it. Notice, too, that both the lid and the lower part of the box have compartments. Make the sides and ends out of white pine or basswood, $\frac{3}{8}$ " thick. The top and bottom may be covered with heavy cardboard or composition wall board.

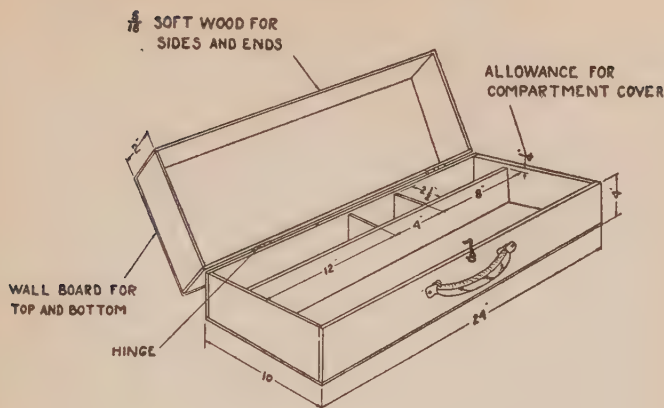
If a bench saw is available in your neighborhood — perhaps your manual training department has one — you can construct the box in one piece. Use 6'' boards for the sides and ends and nail on your top and bottom covering. Then take your box to the bench saw and rip it through, 4'' from the bottom. This guarantees an exact fit between the lid and the bottom part of the box.

The cover is attached to the bottom by three strong hinges — the box is too long for just two hinges. The lids on the inside compartments are held with strong catches, available at any hardware store. Be sure that these catches are strong enough so that the compartment lids will not spring open allowing your tools to drop out and destroy your fragile wings and balsa frame.

The handle should be attached to the exact center of the top to insure balance. Imitation leather may be used for covering the box and improving the appearance. Hot glue can be used for this operation. Brass fittings, such as corners, lock, etc., can be obtained from any hardware store. The indoor box shown in Drawing 13 can be built in the same manner.

The tools required for model-building are very limited, but should be as complete as possible. A pair of round nose pliers, a small block plane (Stanley 100 or 101 is only 3 1/2'' long), a pair of wire cutters, a good sharp knife, a few old razor blades, and when possible an alcohol lamp make up a very good kit.

For working balsa wood one must have sharp tools; a knife or plane that will not hold an edge is useless. Good pliers may be purchased at any hardware store; the wire



AIRPLANE BOX

NO. 13. INDOOR BOX

cutters must be of good quality or they will not be able to cut piano wire.

Model-building requires the use of strong light material if the models are to be successful with long flights. Prior to the World War, wood, such as spruce, white pine, and birch, was used almost entirely by model-builders. Within the last few years they have used almost entirely the extremely light wood known as balsa.

Balsa is a tree grown in the tropical jungles, in appearance resembling the North American cottonwood. The name 'balsa' is the Spanish word for soft, and was given to the wood because it was used for rafts to float heavy woods, such as mahogany, down the rivers. The botanical name is *Ochroma lagopus*. Balsa is by far the lightest wood known, weighing from six to seven pounds per

cubic foot, approximately one half the weight of cork. Although extremely light, balsa has half the structural strength of good spruce, being the strongest wood known weight for weight. Because of these properties, it is far superior to any other wood for model work.

The problem of just what makes the best covering for the airplanes is duplicated in the models. Scale models (non-flying) usually are covered with cloth, either a good grade of linen or Chinese silk being preferred by most model-builders. This can be doped with a good commercial nitrate dope which shrinks and waterproofs the cloth. A coat of lacquer or varnish will give a smooth wear-resisting surface. Berry Brothers, Detroit, Michigan, have completed a great deal of research work on aircraft finishing and have prepared a booklet on the subject which they will be glad to mail to any one on request.

For the 'flying-stick' models, where lightness is essential, we use Japanese imperial tissue for covering. This paper is extremely strong in comparison to its weight and is easily applied. For outdoor models, it can be doped by using a mixture composed of one part of banana oil to five of actone. If the dope isn't strong enough, increase the amount of banana oil.

This commercial banana oil or bronzing liquid is also used as the glue to fasten the Japanese tissue to the frame. It dries very rapidly, holds extremely well, and adds very little weight. Some of the commercial banana oil is very thin. This is useless for models, as it will not serve as a glue at all. Good banana oil is of about the same consistency as castor oil.

There are a number of different kinds of cements on the market made exclusively for model building. Most of these are composed chiefly of celluloid dissolved in acetone. Since it is impossible for the amateur to get the most efficient proportions, it is always best to purchase a well-known brand. The cement prepared by George D. Wanner & Company is as good as any. It is uniform in quality, colorless, and may be purchased in either ten- or twenty-five-cent tubes. The use of tubes prevents evaporation, insuring uniform quality until all the cement is used. This cement is waterproof, flexible, tough, and oil-proof when dry. It is about the only adhesive that can be used to fasten the small metal parts to the wooden pieces without the use of thread binding. When a good clean job of cementing has been done, the wood will break before the cement will give. Wooden parts, such as fuselage sticks, may be repaired again and again with this material, by butt joining and splicing, and the joints will successfully withstand the enormous strains exerted by the rubber motors.

Early model-builders used reed for forming wing tips and other curved parts of their plane requiring the use of wood. Later model-builders substituted bamboo, which can be bent when heated to any desired shape, and because of its great strength can be split into much smaller sizes than would be practicable with reed. Bamboo is still much used in model-building, although, because of its weight, it is eliminated when practicable in favor of balsa. This has been most noticeable in the design of endurance models where weight is one of the chief factors.

Probably the hardest job for the beginner is the bending of the piano-wire parts. Because of its strength, its resistance to bending, it makes excellent metal parts for airplanes. Model clubs should purchase special piano-wire cutters for the use of their members, as this wire will very quickly ruin a pair of ordinary cutters.

The wire is sold by gauge number and comes in diameters ranging from .0029 to 0.146 inches. The sizes used most commonly in model work are given, with their gauge number, below.

GAUGE NUMBER	DIAMETER OF WIRE
5	0.014
6	0.016
7	0.018
8	0.020
9	0.022
10	0.024
11	0.026
12	0.029
13	0.031
14	0.033
15	0.035
16	0.037

CHAPTER VIII

CONSTRUCTION DETAILS

IN model-building, wings are usually classed as either single-surface or double-surface. The single-surface wing consists of a framework covered on the upper side only. The double-surface wing has a framework, with ribs shaped to a given airfoil section, covered on both the upper and lower surfaces. Such a wing is often spoken of by model-builders as a built-up wing.

Invariably the beginner questions the wisdom of covering the single-surface wing on the upper surface. However, if he remembers that we obtain the greatest amount of lift from the upper surface, he will readily understand the advantage gained. One does not wish to have his spars and ribs protruding above the upper surface setting up eddies in the airflow which would reduce the lift and increase the drag.

Since the indoor model does not have to withstand breezes, the spars and ribs can be made very light. Since the added weight of a built-up wing more than offsets the lift gained, the model-builder uses the single-surface wing almost exclusively in building his indoor planes.

The first of these models were built with a non-cambered single-surface wing. Such a wing was very stable, as it had the characteristics of a flat plate. (See chapter on Airfoil Sections.) This advantage was offset because of the poor lifting qualities.

The next step was the use of a single-surface wing with a given camber. It was believed that such a wing would possess many of the characteristics of the double-surface wing while still maintaining the lightness of the single-surface wing. At first all experiments with these wings on indoor tractors failed because of the instability of the new wings when used on the fuselages designed for the old flat-plate single-surface wings.

Early in 1928, Ernest McCoy, a member of the Michigan Model Airplane Club, conceived the idea of changing the design of the fuselage to offset the instability of the wing. His first efforts resulted in the design of the so-called Mystery Ship described in this book. This was, without question, the greatest step forward in the designing of model airplanes that has been made in the last fifteen years. It was the direct cause of moving the indoor record up from 207 seconds in 1927 to 513 seconds in 1929.

The Baby R.O.G. and the Indoor Endurance models described in this book are the best examples of the old flat-plate single-surface wing. The Mystery Ship, the Senior R.O.G., and the Culver Tractor are examples of the cambered type, single-surface planes.

Abgarian curved the ribs of his Mystery Ship to the median line of the Clark *Y* section. (See Drawing 22.) He reasoned that if the lift of a section varies as the amount of the median line, the median-line curve should give the characteristics of that section as near as it would be possible to obtain on a single-surface wing. Later experiments have convinced him that a wing with a slightly increased camber will give better results. This

is partially due to the fact that with a shallow curve much of the effect of the camber is lost by a tendency of the wing covering to sag.

In order to avoid needless repetition, we will describe thoroughly the construction of one single- and one double-surface wing. We will explain all the steps in the construction as well as the various methods used so that the reader can apply the information to any of the planes described in the book. The experienced model-builder objects to a repetition of construction details already familiar to him. The beginner requires detailed instruction for every step. By devoting a chapter to construction details, we have killed two birds with one stone. The beginner can use it whenever it is necessary and the expert can, with his superior knowledge, ignore it.

Let us turn to page 107, Drawing 16 of the original Baby R.O.G. This plane has a non-cambered single-surface wing. Notice that the wing is not flat laterally, but forms a flat 'V.' This angle is called the dihedral angle. Its purpose is to give stability to the plane by lowering the center of gravity. This angle is obtained by bending the wing spars, and in order to get the same angle on each spar they are bent while in one piece. For the Baby R.O.G. you need a balsa spar $1/32 \times 3/8 \times 10''$. After finding the exact center, the positions of all the ribs are marked on the spar with a lead pencil. The spar is then held over the spout of a tea kettle until it is thoroughly steamed (about two minutes) and then bent to the required shape. Another method is to hold the spar over an open flame until it will bend. This method is more

difficult, due to the danger of overheating and charring the spar. After the spar is bent, two balsa strips $3/32''$ wide are split from it. By laying one half flat on the workbench and guiding the knife with a metal edge rule the piece is carefully split off. One should not attempt to cut through the wood with one stroke, but should make several, cutting deeper each time, until the piece is split. This method should always be followed in splitting flat balsa or bamboo.

Some boys prefer to use a simpler method for getting the dihedral angle in their wing spars. Probably the easiest method is that of cutting the spars in half at the center and cementing them together again, forming the required angle. If we were to use this method, we would first split off our two spars $1/32'' \times 3/32'' \times 10$. We could then cut these spars at the center to form four $5''$ spars, or merely cut them part-way through on the under side so that the spar will bend. In the first case the ends of the spars would have to be cemented together, forming a butt joint, while in the second the spars are bent to form the required angle and the center given a coat of cement to make a solid joint and prevent further splitting. A block placed under one spar, while the other rests flat on the table, will maintain the required angle while the joint is drying. A still later method than either of the above methods, is to join the wing spars together by the wing clips. This method was first successfully used on the Wanner Number One Baby R.O.G. Then on the Senior R.O.G. This method permits one to build up his wing in halves, thus simplifying the covering. These

halves, when finished, are joined together by the wing clips which are formed to give the correct amount of dihedral angle. The latter method also makes it extremely easy to alter the wash-in and wash-out on the wing when adjusting for flying.

Most of the early indoor models had curved wing tips formed from bamboo. These were made by bending a piece of bamboo over an open flame to the required shape. Bamboo when heated becomes very pliable and can be bent to almost any angle. A candle flame, or the flame from an alcohol lamp, was used the most for bending bamboo. Then it was discovered that an electric soldering iron gave just the right heat and it became the most popular. Don't forget that bamboo will bend under a very slight pressure when heated to the right temperature and will break if one attempts to bend it before it has reached this temperature. In bending bamboo, it is well to use a piece much larger than required for the finished part, as these pieces are very thin and will char quickly when held over a flame. A larger piece will not char, and when more than one piece is to be used on the same model, permits one to split off pieces identical in shape. This method is always used in forming wing tips and landing-gear parts of bamboo. In bending the tips for the Baby R.O.G. (Drawing 16) one should use a piece of bamboo $1/32''$ thick, not less than $1/8''$ wide and approximately $6\ 1/2''$ long. If your piece is thicker than the above, it can be planed and sanded until it is the required size. Unless the piece is uniform in thickness, it will tend to bend sharply in the thinner parts, making irregular, un-

sightly looking curves. When the piece has been bent to the required shape, it can be split into a number of wing tips by using the point of a sharp knife and carefully working from one end to the other. While bending the tips, one might as well bend the frame for the rudder. This is done in exactly the same manner as was used in the tips. The exact shape can be had by first making an outline drawing of the finished part and then bending the bamboo to this drawing. This method is also often used by beginners for obtaining the proper wing-tip curves.

Notice that the later type models have done away with curved bamboo tips and rudders and are using instead square balsa tips and rudder frames. Although these don't look quite so neat as the curved bamboo parts nor are they as strong, yet, because of their saving in weight and ease of construction, they have almost supplanted the bamboo types. Both the Mystery Ship and the Senior R.O.G. are good examples of the all-balsa type.

Notice that the R.O.G. also calls for $1/32'' \times 1/32'' \times 2''$ bamboo ribs. These may be replaced by $1/32'' \times 1/32'' \times 2''$ balsa with a slight sacrifice in strength, but considerable saving in weight. When the ribs are cut to size, the frame can be assembled. The bamboo tips are joined to the end of the spars using a half lap joint. The ribs are butt-jointed between the spars as shown in the drawings.

The next step is the addition of wing clips. These are made from .016'' diameter music wire. Notice that the rear clip is $1/4''$ higher than the front clip on the Baby R.O.G. models. This difference in size sets the wing on

the motor stick at an angle so that the leading edge is higher than the trailing edge. This angle is the angle of incidence. Too great an angle will cause the plane to stall while in flight. Too small an angle will prevent the plane from climbing properly. Remember that unless the clips fit the motor stick snugly, the wing will be constantly coming off while in flight.

With the wing clips cemented in place, we are ready to cover the wing. For the beginner this is probably the most difficult operation of the entire job. A perfectly smooth tight cover seems almost impossible to him, but with a little practice it becomes increasingly easy until he marvels at his early mistakes. In covering the wing, cut a piece of Japanese tissue so that it is about one half inch larger than the wing on all sides. Some fellows prefer to cover each half of their wing with separate pieces of paper, joining them at the center rib. This is not necessary and does not help much except in the case of the cambered wings. Begin the covering by painting the center rib with your cement. Some model-builders prefer to use banana oil (bronzing liquid) for this operation. If you use Wanner cement, you can obtain excellent results by painting the rib with cement and immediately wiping it off. The paper must be quickly laid in place or the remaining cement will have dried. This method gives results equally as good as obtained with banana oil without the necessity of waiting for your covering to dry in place. It also eliminates one more item from the fast-growing model supply list.

When the paper is fastened to the center rib, paint the

next rib and the portions of the leading edge and trailing edge between them and lay the paper in position. Continue in this manner, rib by rib, until the entire wing is covered. In covering cambered wings, it is better to paint the leading edge of one half first and attach the paper. Then the paper is folded back toward the trailing edge, cementing it as we proceed.

Paper used in covering wings should be absolutely free of all wrinkles. These can be removed by ironing between sheets of thicker paper. Before proceeding, it must be allowed to retain the room temperature. Abgarian does his covering over an ironing-board which he keeps warm by frequent ironings. He does this to give the paper approximately the same heat that it will incur when flying high up in an auditorium. He claims that it prevents warping due to excessive heat found near the ceilings of large auditoriums.

If the paper is free of wrinkles, one should have little, if any, difficulty in getting it to lie flat in place. One should not attempt to stretch it, but should only make sure that it is taut. The Wanner method of constructing wings is just the reverse of that described above. Wanner kits (A.M.L.A.) have all the spars and ribs printed on the wing covering. This is laid flat on the table over a strip of wax paper (to prevent the cement penetrating the tissue and sticking to the table) and the whole is held in place by pins. After all the ribs and spars have been cut to size, they are coated on one side with cement and laid in place on the pattern printed on the covering. Next the ends of the ribs and tips are cemented to the spar and leading edge and the wing is ready for trimming.

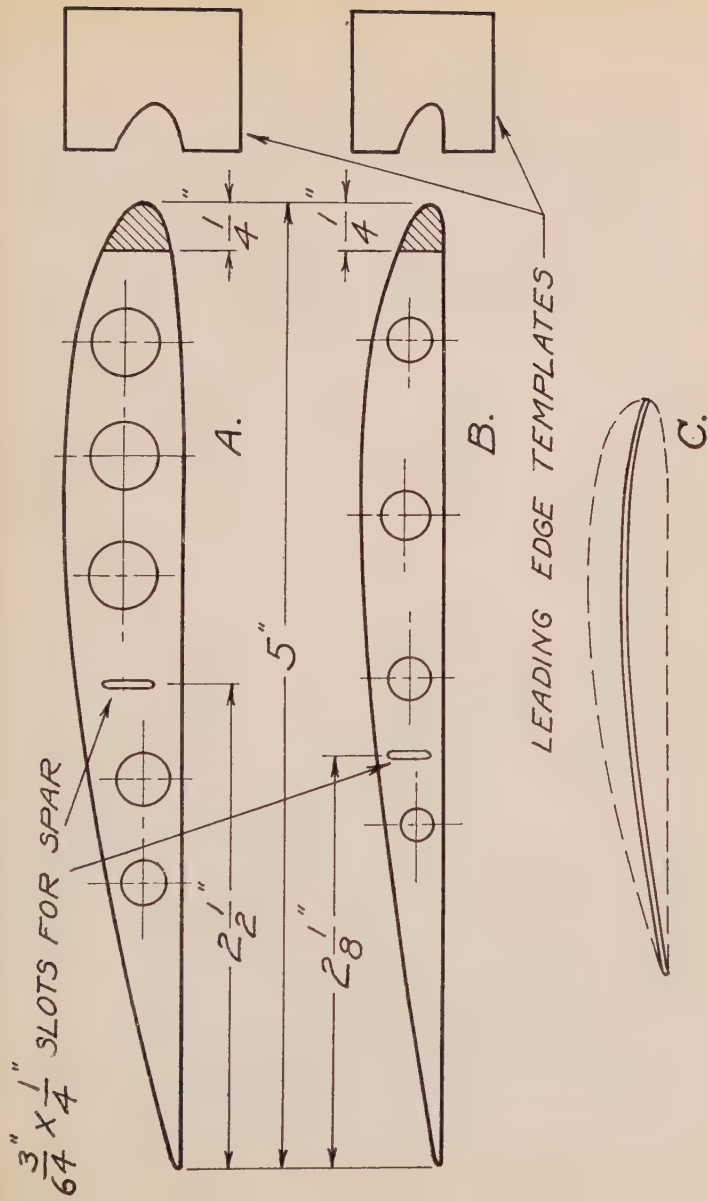
Excess paper may be trimmed from the wing by using a razor blade or shears. Some fellows prefer to trim their wings by using fine sandpaper on the outer edges. After trimming, the loose edges may be fastened in place by painting with a mixture of five parts of acetone to one of cement.

Drawing 15 shows the front view of a wing used on a plane with a left hand propeller. Notice how the leading edge is warped up on one side and warped down on the other. This is known as wash-in and wash-out. A wing is said to have wash-in when the leading edge near the tip is warped up. This increases the lift as it enlarges the angle of incidence. The wing is said to have wash-out when the leading edge is warped down. This reduces the lift as it decreases the angle of incidence. Wash-in and wash-out may be obtained by twisting the wing until it retains the required shape. The same results can be obtained by bending the wing clips so as to twist the wing to the required position.

Wash-in and wash-out are used on indoor planes for two reasons. First, to offset the propeller torque, and, second, to aid the rudder in turning the plane in a small circle. If an indoor plane is wound and then held by grasping the propeller with the rest of the model free, it will begin to revolve about the propeller shaft. In flying, the propeller meets with a similar resistance as it revolves. The plane then has a tendency to revolve about the propeller shaft. This reaction is known as the effects of torque. Propeller torque has a tendency to cause the plane to revolve in the opposite direction to that of the

propeller. This force on the plane causes it to bank. Too much torque will cause the plane to go into a spiral dive. By giving the left wing wash-in and the right one wash-out, this tendency can be overcome, as the lift is increased on the left wing offsetting the effect of the torque. A slight decrease in wash-in will cause the plane to turn in a smaller circle. This can also be accomplished by turning the rudder slightly. Usually it becomes necessary to add some wash-in with any increase in rudder. Wash-out on the right wing decreases the lift on that side and decreases the amount of wash-in required. Increasing the amount of left rudder usually has to be compensated for by additional lift, which is obtained by moving the wing forward on the motor stick. Decreasing the amount of left rudder requires less lift and the wing is moved to the rear on the motor stick. Gliders that have a tendency to circle in flight can be made to glide in a straight line by twisting a small amount of wash-in into the wing on inside of its circle.

Drawing 14 shows two airfoil sections so drawn that they have a chord of exactly five inches to correspond with the wing for the outdoor twin pusher shown in Drawing 30. The upper section marked 'A' is the Clark Y. This section has been used on such ships as the Curtiss Hawk, Spirit of St. Louis, The Stinson Bi-plane, and many others. This is a good section for the beginner, as it is thicker than the sections used on the average twin pusher. This gives a wing that has plenty of lift and is unusually strong because of the heavy spar through the center. Section B has been used on more



NO. 14. HERE'S YOUR WING SECTION

Most beginners use the thicker one, marked A. Make a tracing, paste it on brass, and cut out a brass template, or pattern. Mark the center of each hole and the ends of the slot by punching a phonograph needle through the brass. Then you can construct each of the ribs for your wing exactly the same.

prize-winning twin pushers than all the other sections put together. Among these are two National Contest winners. It is not as good a section for the beginner as the Clark Y because of the shallow spar depth. Unless extreme care is used, the wing will warp while under construction.

Drawing 3 shows how to lay out an airfoil section. If you decide to use either 'A' or 'B,' these can be transferred directly by pasting the page on a sheet of brass and cutting to the outline. This is done with the snips and then smoothed with a file.

The slot for the spar may vary in size. The drawing calls for $3/64 \times 1/4''$. This is just right for the endurance planes, but the beginner should have a larger spar, especially when using the Clark Y. A slot $1/8'' \times 5/16''$ for the Clark Y and $1/8'' \times 1/4''$ for Section B is recommended. Do not attempt to cut this slot in your template, but drill a small hole at each end of the slot, using a drill with a diameter equal to the width of the slot. If you can't get a drill, you can locate the ends of the slot by driving a Victrola needle through the brass template. This permits you to mark the ribs through these holes. You must get this slot exactly the same in each rib or they will not line up and your plane will be useless for flying. For this reason you must have some accurate method of transferring the slot from the template to the ribs.

The round holes are to lighten the ribs, and although not essential, they help to cut down weight considerably. The best way to transfer these is to use the Victrola needle method of making a hole in the exact center of the

circle. You'll notice that the holes are of different sizes. The three larger holes, Section A, should have a $3/8''$ diameter and the other two should have diameters of $5/16''$ and $1/4''$ respectively. There are only four holes in Section B, as it is a thinner section. The largest of these is $5/16''$ in diameter, the next two have diameters of $1/4''$ and the smallest one $3/16''$.

This completes the template of the wing, with the exception of the leading edge. You will notice how the section is cut off in the drawing $1/4''$ back from the leading edge. This part of the wing is formed by a solid balsa beam shaped to the leading edge curve. The ribs are cut off and butt-jointed to this beam. Notice the photograph of the wing tip assembly opposite page 198.

The leading edge template may be made by pasting the drawing on a small square piece of sheet brass and then finishing it to the line with a file. A six-inch round needle file is good for filing the curve. When this fits the leading edge of the rib template, you may cut off the shaded section as shown. You should take special care in cutting this to get it perfectly square.

This completes the templates and you are now ready to cut out the ribs. The stock from which the ribs are made should be about $1/16''$ in thickness and uniform throughout. The template is laid flat on this and the rib is cut out around it with a razor blade or sharp knife. Without removing the template, the slot and lightening holes should be marked with a sharp lead pencil or Vicrola needle through the center holes. Remember, all thirteen ribs must be identical.

Now, with a razor blade or the point of your knife cut out the slot. If you grind a half-circle in the cutting edge of the razor blade $1/16''$ from the end, it will make a very good tool for cutting out the slots. The lightening holes can be drawn with a compass and then cut out with the razor blade, or, if you have wood bits, the holes can be cut out by turning these into the wood by hand until the knife edge at the bottom enters the wood, and then removing it and repeating in the same manner from the other side. This will allow the center section to drop out, and, if the bit is sharp, should leave a smooth clean hole.

The two leading edge beams are made next. These are made of balsa, and their shape is clearly shown in the drawing. The curve can be roughed out either with a small plane or jackknife. You should frequently check this with the brass leading edge template. When almost to size, the final shape may be given to them by using the leading edge template as a scraper. This is done by drawing the scraper toward you and at the same time inclining it toward the beam. You must be careful not to let the template twist in your hand, as this will gouge and spoil the shape of the leading edge.

Drawing 15, Figure 6, shows a built-up rib that has been used very successfully. It requires a little more patience, but the saving in weight is well worth the trouble. In order to get all the ribs exactly alike, we must have a forming jig. This can be made by fitting $1/16''$ thick balsa strips around the brass template. These are cemented to a flat board, on which an outline drawing of the finished rib has been made. When finished, the

template should just drop into the depression without any clearance. Next, small pieces of balsa are cut out and cemented between the lines so as to leave a space $1/16''$ wide for the rib parts. When finished, the jig is painted with a thin coat of hot paraffin. This will prevent the cement sticking to the jig when the rib parts are being joined together; $1/16''$ square balsa strips can be cut to length and fitted into the spaces left for them and the whole cemented together. The leading edge curve may be had by steaming a short piece of balsa before bending. This is butt-jointed to the upper and lower cap strips.

Figure 4, Drawing 15, shows a hollow leading edge. The $1/32''$ thick balsa strip is thoroughly steamed and then bound in place about a solid wood leading edge form until dry. This type leading edge is less than half the weight of the solid shown in the twin pusher (Drawing 30) and is almost as strong. Notice how the ribs are cut out to receive them.

Another form of leading edge is made by inserting a $1/16'' \times 1/8''$ leading edge spar into a slot cut to receive it in the nose of the rib. Since the spar is only $1/16''$ thick, a very little sanding will make it conform to the curve of the leading edge. When this type of leading edge is used, additional false ribs are needed to maintain the shape of the section, as otherwise the paper would sag between the ribs when ordinary spacing is used.

Now you are ready to make the tips. Drawing 30 shows round tips on the wing, but you may change these to any shape you wish. The round or elliptical ones are more efficient, but some boys prefer the looks of the

positive rake type. Many different shapes can be copied from planes shown in aviation magazines. As these tips are rather hard to cover, many boys let the end rib act as the tip on the first wing. This would give you a square tip.

If you decide on other than the square type, the tip should be made of bamboo. In preparing bamboo for bending, it should be carefully split, not cut, as near to the required size as possible. When this is done, you should finish the piece by splitting small slivers off the side and then sandpapering until the piece is uniform in thickness the entire length. This is extremely important if you wish to get even bends in the bamboo parts. Variations in size will always make sharp, unsightly bends instead of smooth, graceful ones.

The bamboo for the wing tips must be $1/16''$ square and $15''$ long. An easy way to check the shape of the tip while bending is by laying it on a full-sized drawing of the curve as you form it. Be sure to bend the ends so that they will gently curve into the leading and trailing edges, forming continuous lines with the outside edges of these. In the case of the leading edge, it must overlap at least a half-inch. The leading edge spar is grooved to receive it. The trailing edge should form a half-lap joint with the tip and when cutting the tip to size, after bending, you should allow stock for these joints. The tip is now split to form two identical pieces and after trimming and sandpapering are ready to assemble.

The trailing edge is made of bamboo, $1/64'' \times 3/64''$ which extends from one wing tip to the other with the

thin side parallel to the ribs. If one wishes an extremely light wing, the trailing edge may be made of balsa. Silk thread has been used successfully for the trailing edge. When the thread is used, it is best to use bamboo between the two ribs which set over the frame to prevent the wing clips from tearing the cover.

You are now ready to assemble the wing. This is done one half at a time. The first step in assembling is to taper the end of the leading edge to fit the wing tips. (See the drawing, Figure 1; also, the photograph of wing tip assembly.) Notice that this is all done on the top so as to leave the bottom of the wing flat. While doing this, groove your leading edge to receive the tip. Now you can taper the end of the center spar to the thickness of the tip in the same manner.

You should make the positions of the ribs on the center spar and leading edge $2\frac{3}{4}$ " apart. Next, shallow grooves are cut into the leading edge at these points with the width of the ribs and about $1/64$ " deep. Now you are ready to slide the ribs onto the center spar, and when these are all checked up for squareness, they may be cemented in place. Cement should be used sparingly but effectively. An easy way to check the trueness of the wing is to lay it on a piece of plate glass or other *level* surface, making sure that every rib touches along the entire bottom. If the ends of any of the ribs have a tendency to rise higher than the others, the slot must be enlarged to permit it to revolve parallel with the rest. The sides of the ribs must also form a ninety-degree angle with the center beam. Next you can cement the leading edge

beam in place, making sure that the end of each rib is fitted into its proper groove and forms a continuous curve with the leading edge. The tips are then cemented in place; a couple of turns of silk thread around the joint of the leading edge and the bamboo trailing edge will help to make it stronger. The trailing edge may be made up of pieces of bamboo half-lapped and bound with silk and securely cemented.

You are now ready to assemble the two halves of the wing. If you place a block under each half in such a manner that the tips are approximately $1\ 1/2''$ from the workbench, you will have the correct dihedral angle. This will enable you with a razor blade to cut down through both of them at the same time. In this manner you will get a perfect-fitting butt-joint for both center and leading edge beams. These beams may also be half-lapped or mortised if you prefer a stronger joint.

Now slip the center rib into place and cement both the joints. The wing should be left on the block for an hour or so until the cement is thoroughly dry. The trailing edge is then finished, completing the frame of the wing.

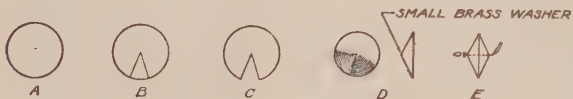
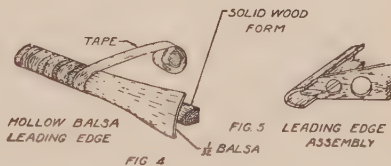
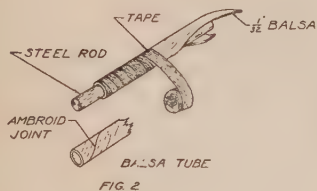
Your next job is to cover the wing with Japanese imperial tissue. Banana oil or Wanner's cement is used to fasten the paper to the wing. The top of the wing should be covered first, then the bottom.

Paint the leading edge of one half of the wing with cement, and wipe off. Then lay the paper in place. The paper should be cut to cover one half of the wing only. The two sheets of paper being joined on the center rib, the top and bottom of the wing may be covered with the

same sheet by fastening the center of the sheet to the leading edge in such a manner as to allow one half to fold under for covering the bottom and the other half to fold over for covering the top. Separate pieces may also be used for top and bottom. When the paper is cemented to the leading edge, the trailing edge is painted and wiped and the paper carefully laid over the top of the wing. Care must be used to prevent any wrinkles from being left in the upper surface. Neither should the paper be drawn overtight. No attempt is made to cement the paper to the upper edges of the ribs. When the paper is in place on the upper surface, the same operation is performed on the lower surface. Next, the surplus paper is trimmed from the leading edge.

The paper may be drawn tight after spraying with water. A small garden spray may be used for this operation. When dry, the wing is ready for doping. A good dope can be made by mixing five parts of acetone to two of Wanner's cement. This will shrink the paper to the frame and will effectively fasten it to the top and bottom of the ribs. Another very good dope may be made by mixing five parts of acetone to one of banana oil. Too heavy a dope will warp the wing from over-shrinking. Too thin a dope will not shrink the paper sufficiently to prevent sagging. The dope made of cement and acetone gives the paper a decided glaze as well as waterproofing it.

The tapered wing offers more of a problem, as one must have a template for each size rib. Probably the easiest way to get these is by laying out the root and tip sections



(see chapter on Airfoil Sections), one on each end of a block approximately two inches long. Balsa wood or pattern pine is the best for this use. If the templates are to be used more than once, pine should be chosen. The block is finished to the two sections drawn on the ends. A straight-edge may be laid on the block to check the center sections. When finished, a rule laid lengthways on the block should touch at every point along its surface. This gives us a tapered block shaped to the root section at one end and the tip section at the other.

Next the block is divided into equal spaces, one less than the required number of ribs or templates. That is, if we require twelve ribs on a side, the block is divided into eleven equal spaces. The block is then sawed into twelve parts at these divisions and the sections obtained may be used as templates for laying out the ribs on thin balsa. Care must be used to see that the corresponding side of each template block be used. If one uses the small side of one and the large side of another, the finished ribs will not fit evenly between the trailing and leading edge spars. If this method is used, one can use the resulting templates to construct a tapered wing of any given span as long as the ribs are kept evenly spaced.

When the wing to be constructed is designed with square grooves for the spars instead of having elongated holes, as shown in the twin pusher drawing, these slots may be laid out on the template block before it is cut up into templates. This is the easiest way possible to get every slot in its correct position.

We have already discussed the use of thin balsa veneer

for making leading edges. Drawing 15 (Figures 2 and 3) shows two more ways in which it is used. Figure 2 shows how a thin balsa tube is made by wrapping the $1/32''$ thick balsa veneer around a metal rod. The balsa must be well soaked or steamed before any attempt is made to bend it around the form. Dressmakers' tape may be used to wrap around it to hold it in place while drying. When thoroughly dry, it may be removed and the joints cemented. Tubes of this type are put to many uses. The helicopter described in this book has a tube motor stick with the rubber bands extending through the center. Albert Mott uses a tube for the tail boom on his endurance tractors. Figure 3 shows the upper part of a pontoon formed of veneer. This is made over a solid form. The shell is fitted with a thin bulkhead and the bottom is covered with Japanese tissue. The whole is made waterproof by painting with a solution of acetone and Wanner cement.

Suitable wheels are usually a problem to the beginner, most commercial wheels being much too heavy for flying models, and as a rule he has to fall back on flat thin wooden ones. The drawing shows a method often used to construct cone type wheels, which are not only very light, but also extremely attractive. Two round discs of drawing paper are first cut out slightly larger than the desired diameter of the finished wheel. A sector or 'V' is cut from this, as shown in C. Then the edges may be folded over and cemented in place, forming a very flat cone. A small brass washer is then cemented to the inside of the cone to form a bearing for the axle. Two of these

glued together make a very attractive wheel. They can be prevented from coming off the axle by cementing a small hub of balsa wood on the axle. Oftentimes a drop of cement on the end of the axle is sufficient.

CHAPTER IX

BABY R.O.G.

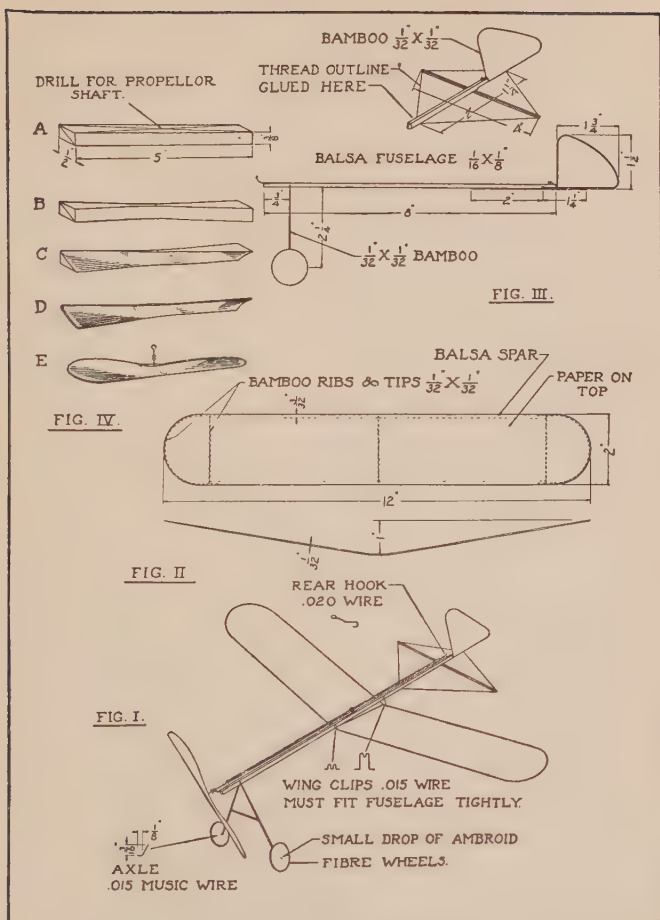
IF you have never constructed a flying model airplane, the Baby R.O.G. is just the one to start on. This little plane—it has only an eight-inch motor stick—can be flown in an ordinary living-room, where it will circle around and around, or it can be flown in the largest auditorium, where it will go sailing up to the ceiling. It will take off like a real plane under its own power (R.O.G. is abbreviation for 'rise off the ground'), and will come gliding down dead stick and make a perfect three-point landing. When it comes to stunting, it has them all beaten. A good Baby will climb seventy-five feet in one spiral, when powered with $1/8''$ -30 rubber motor, or it will make as many as nine perfect loops in one flight. The members of the Airplane Model League of America purchased over seventy-five thousand Baby R.O.G. kits during a period of eight months. This is a record for any type of model plane. As it is impossible to obtain the balsa wood, piano wire, and other special model materials in many communities, these kits are very helpful, as they contain everything necessary to construct the planes, including the metal parts all made up. The George D. Wanner Company, of Dayton, Ohio, has arranged to furnish the parts separately to those boys who prefer to construct the greater part of the plane themselves.

The Baby R.O.G. is a flying-stick model. Remember,

when you start building it, to follow directions carefully and to strive constantly to make the parts as light as the drawings indicate. The drawing (No. 16) shows all the parts with the details clearly shown. If you have difficulty in understanding the directions, refer back to the detail drawing of that part. Do not start work until you have a mental picture of each part and know exactly where it belongs.

The fuselage — the part running from the propeller to the rudder — is shown in Figure III. It is a single stick, eight inches long, planed and sanded to $1/16'' \times 1/8''$. Be sure not to make it thicker than that, because you will want to keep the plane as light as possible. Balsa is the best wood for the fuselage. It is easy to shape, strong, and only half as heavy as cork. If you prefer, however, you can use any straight-grained soft wood, such as white pine or basswood, although these are heavier and will cut down the time your ship will stay in the air.

Now for the front bearing. It can be made by cutting a piece $1/2''$ long from a small cotter pin or by flattening out a small brad. A hole is drilled with a No. 72 drill, as near one end as possible. The piece is then bent to form a curved 'L.' This can then be cemented flat to the end of the motor stick. Study the drawing. If the cotter-pin bearing is used, the flat surface is laid next to the wood. In cementing the bearing in place, the entire end of the motor stick is painted with cement. It is not necessary to bind the bearing with thread, as the airplane cement will withstand more strain than the wood. The rear hook is next bent to conform with the drawing. This can



easily be formed with the help of a pair of round-nose pliers. All the wire parts of this model are made from .016 music wire. The hook is fitted around the rear end of the motor stick and cemented in place. (See the drawing.) The can is added next. The drawing of the Senior R.O.G. shows the shape better. This is cemented to the center of the stick as shown. When in place, the loop should be set about $1/4''$ above the stick, so that a string stretched from the front bearing to the rear hook will pass through the center of the loop. The can is used in model airplane construction to prevent the motor stick from breaking under the strain of the rubber. It acts in the same manner as the eyelets on a fishing-rod.

The rudder is formed by bending a bamboo frame and covering it with Japanese tissue. Figure III shows just how it is shaped and the sizes of the three sides. The easiest way to get the correct shape is by making a full-size drawing of the rudder and then bending the bamboo to it as a pattern. Bamboo-bending is described in detail in Chapter VIII, Construction Details.

Later models are using all balsa tail surface instead of the bamboo. Both the Senior R.O.G. and the Mystery Ship are good illustrations of this type of tail surface. If you prefer the lighter type, substitute it on the Baby R.O.G. The shape of the tail surface and rudder may be changed without affecting the performance of the model, provided the area is not changed.

To attach the rudder to the fuselage, study Figure III. With your knife cut a small groove in the bottom of the fuselage to receive the projecting base of the rudder.

Cement the two together so as to form a continuous line with the under side of the fuselage. Be sure, too, that the rudder stands up perpendicularly.

To make the tail, first cement a stick of bamboo, $1/32''$ thick and 4'' long, to the under side of the fuselage, $3/4''$ from the end, as shown in the drawing just above Figure III. You will notice that the fuselage is notched to receive this cross-piece. To make the frame of the tail, tie a piece of silk thread around the bamboo base of the rudder, one inch back of the end of the fuselage stick. Tie the thread so that there will be seven or eight inches of thread on each side of the knot. Then stretch the threads taut around the ends of the bamboo cross-piece and forward to the fuselage, at a point two and a quarter inches in front of the bamboo cross-piece. When you are through, you will have a four-sided thread frame, as shown above Figure III. It is fine, delicate work, but not at all difficult.

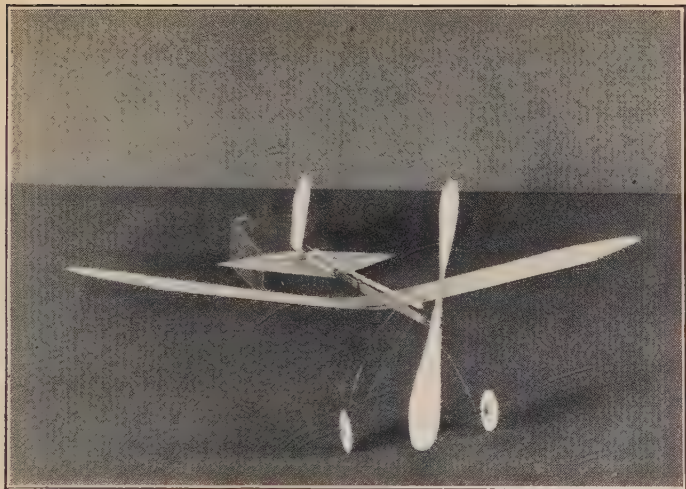
Now get your Japanese tissue paper and iron it out smooth. If you have used a hot iron, let the paper cool to room temperature before covering the tail and rudder. First of all, cut a piece of the tissue slightly larger than the frame of the rudder. Then paint the bamboo frame of the rudder with cement or banana oil. Be sure to wipe off all surplus cement before applying the paper. Lay the paper on the frame, being careful to smooth out all wrinkles. After you have covered the rudder, trim off the extra paper and coat the cut edge with banana oil to make it stick to the frame. Cover the tail in the same way as you did the rudder, but in this case do not fold

the edge of the paper over the silk thread. Simply leave about $1/32''$ of paper extending beyond the thread on all sides. You can get a neat edge on the tail by placing a steel edge rule flat on the paper and trimming with a razor blade.

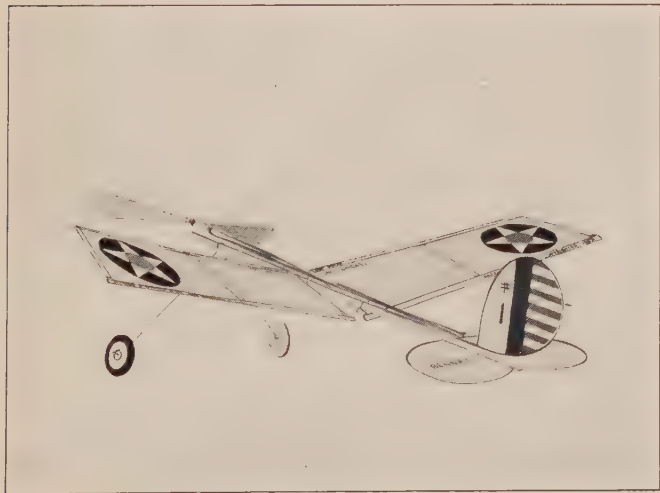
The wing isn't straight, but it is in the shape of a very flat 'V,' as shown in Figure I. The angle formed by the two halves of the wing is known as the dihedral angle. The more pronounced the dihedral angle, the more stable will be your plane — and the less distance it will travel. You had better make your first wing with a fairly pronounced angle, so that your plane will be stable. Later, when you have had more experience, you can try a flatter wing. The flatter wing, you will find, permits your plane to turn more easily, besides giving it more endurance in the air. Another point you will learn is that landing-gear helps to stabilize the plane, so that when a plane is equipped with landing-gear the wing does not need as large a dihedral angle.

To construct the wing, cut out a flat piece of balsa or other soft wood $1/32'' \times 3/8'' \times 10''$ long. Balsa is much to be preferred because it is lighter. A complete description for the construction of this type of wing will be found in Chapter VIII. The wing can be lightened considerably by substituting balsa for the bamboo ribs and by using square tips formed from a single balsa rib. This type of wing is not so strong or so good-looking, but is very light and preferred for duration models.

You are ready, now, to bend the two wing clips, of .016 music wire, as shown in Figure I. Be sure to bend them



THE BABY R.O.G. FINISHED, USING THE WIRE LANDING
GEAR



WANNER BABY R.O.G.
Notice method of building wing in two parts

so that they will fit the fuselage stick tightly, or the wing won't hold. Note, too, that the rear clip is $3/8''$ higher than the front clip. That is to give an upward slant to the wing, so that the plane will climb. Take care with the two clips, because if this upward slant — called the angle of incidence — is too great, the plane will try to climb too rapidly, and will stall. If it is too small, the plane won't climb. When you have the clips shaped just right, cement them exactly in the center of the two wing spars, as shown in Figure I.

The wing is now covered with Japanese tissue. Remember that the neater the paper is put on, the more efficient your plane will be. Study the method of covering wings given in the chapter on 'Construction Details.'

The propeller is carved from a block $3/8'' \times 1/2'' \times 5''$. In all the models described in this book, we use the method described in the chapter on 'Propellers.' The efficiency of the entire model depends greatly on the propeller, and one should spare no effort to get it as thin and light as possible.

After you have successfully finished and flown your Baby with the five-inch propeller, you can go out after the R.O.G. record by constructing an extra propeller. Use a $1/2'' \times 3/4'' \times 6''$ block for this one. You may have a little difficulty in getting the plane to fly with the larger propeller, but when it does, it should increase your time to 180 seconds.

The propeller shaft is shown in Detail *E*, Figure IV. Study, in addition, Figure I, until you understand just what it is for. Now take a piece of .016 music wire about

1 3/4" long and pass one end through the propeller, as in Figure IV. Bend the front end into a square 'U' and cement it into place. Now bend the rear end, as in Figure IV, so that it will easily engage one end of the rubber motor. Then slip on a couple of small washers, or extremely small beads, to prevent friction between the propeller and the front bearing. Next, slip the hooked end of the shaft through the hole in the front bearing. This puts the propeller into position on the fuselage, as shown in Figure I.

Your motor is a band of .045 square rubber, tied in the middle with a square knot. The band should be long enough to allow about an inch of slack when one end is hooked on the propeller shaft and the other end to the rear hook.

Bend your landing-gear from .016 music wire. The chief requirement of the gear is that it keep the front end at least two and a half inches off the ground, so as to clear the propeller. The top of the gear fastens to the fuselage just as the wing clips do.

You do not need detailed instruction to shape the landing-gear. Nearly every boy varies this part of the plane to suit himself. You can make wheels either of 1/16" thick balsa or of paper. You may arrange either to have the wheels turn on the axle, or have the entire axle turn in a bearing made by looping the bottoms of the supports. Work it out to suit yourself, but be sure to have the front end of the plane at least two and a half inches off the floor.

After you have clipped on your landing-gear and at-

tached your rubber motor, you are ready for the test flight. Your work is done and your fun is about to begin.

Before you wind up the motor, let the plane glide from your hand to the floor. If it dives too rapidly, set the wing forward slightly and try again. If the plane tries to climb and then settles on its tail, set the wing back. When the plane glides evenly, it is ready for a flight.

If you are flying outdoors, leave the rudder straight. If you are flying in the house, curve the rudder to the left by holding it close to your mouth and breathing on it while you bend it slightly with your fingers. The amount of bend depends entirely upon the size of the room in which you are going to fly. If your plane, in flying, goes into a spiral dive, it is a fairly sure sign that you have the rudder bent too much. Sometimes an increase in wash-in will overcome this tendency. See chapter on 'Construction Details' for more information on the use of wash-in and wash-out. The plane will not be injured by striking the wall. If you have followed directions the model will be so light that it will careen off without damage.

To wind the motor, hold the fuselage between the thumb and forefinger of the left hand, with the propeller toward you. With the forefinger of the right hand, turn the propeller clockwise. When the rubber strands show a thick row of knots, they are tight enough (about 250 turns). Turn the plane away from you, still holding the propeller. When you are ready, release the propeller with the right hand and let go the plane with your left.

Do not chase it or grab it. Just watch it shoot away from your hand, and then circle and climb. In no time at

all it reaches the ceiling, hits it, swoops downward, and climbs again. If you have built the plane exactly according to the drawings — which you probably will not do on your first attempt — the Baby R.O.G. will stay in the air more than a minute, gracefully circling and then coming to earth. If the first one does not give you a long flight, you have probably made the parts too heavy. In that case, try again. No expert model-builder to-day — no national contest winner — ever built a perfect plane on his first attempt. The fun will come when you construct others, profiting by your experiences to build a model that will perform like an actual ship!

Figure III shows the construction of a baby fuselage with a bamboo landing-gear. Many boys prefer this type over the wire one, as it is much easier to construct and considerably lighter. If you decide to use this type, you will have to cut down the size of your tail surface as shown in the drawing. Both landing-gears have their advantages. The wire one, although heavier, is stronger, and can be taken off the fuselage to be packed away in your kit. The bamboo struts, because they are cemented onto the fuselage, must be left assembled at all times and take up more room in your airplane box.

Drawing 17 gives the dimensions for the McCoy Baby Biplane. This plane is very similar to the Baby R.O.G., with the exception of the wing. All the dimensions necessary for constructing this plane are given, and after one has constructed a successful Baby, he shouldn't have any difficulty with the Biplane.

If one cares to, he can use the baby fuselage for this

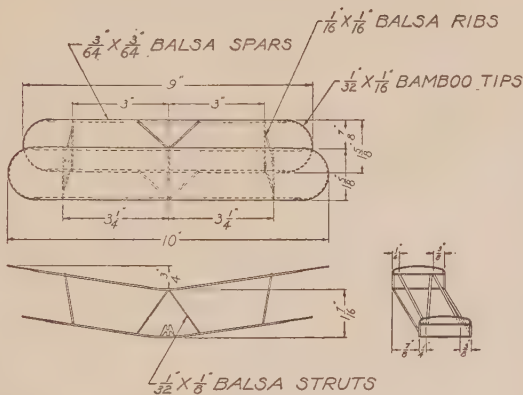


FIG. 1.
WING ASSEMBLY

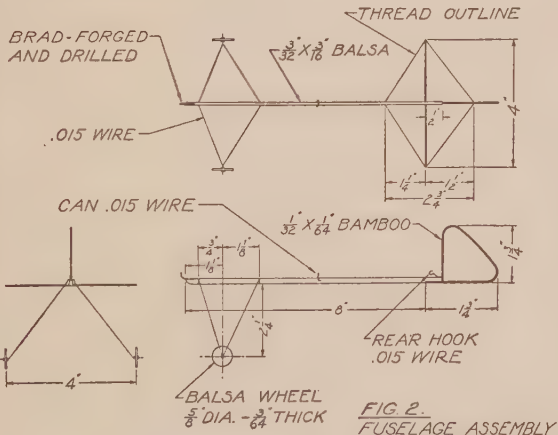


FIG. 2.
FUSELAGE ASSEMBLY

F. L. Zwickley 2A

model, although it is much nicer to have one for each plane. The wing is given a positive stagger, the upper is set $7/8''$ ahead of the lower. They are connected by N-type struts of $1/16''$ square balsa. The four center spars are placed to allow the fuselage to slip in or out at will. The landing-gear must be of the wire type so that it can be detached when the plane is not in use.

CHAPTER X

SENIOR R.O.G.

JIMMY SHIELDS wanted to win an airplane model contest.

'My old Baby Rise-Off-the-Ground won't do it,' he worried. 'No flight of a hundred seconds or so will be good enough. And yet it's a Baby R.O.G. contest. The ship has to be able to rise or land on its own wheels; it can have only eight inches of rubber, and it must be lighter than anything I've ever built. My guess is that it'll have to fly close to three minutes, too. These Detroit R.O.G. builders are good.'

Jimmy knew his problems, and he started experimenting. Finally he had a new rise-off-the-ground model — we call it the Senior R.O.G. It weighed less than a tenth of an ounce; it had a tail boom that made its total length fifteen inches, though it had only eight inches of motor; it possessed an inverted rudder that lowered the center of gravity and thus helped to stabilize the model; and it had a cambered or curved surface wing.

He figured it this way: 'Lengthening the model moves the tail farther from center of gravity, hence increases stability. Setting the tail out on a boom, at a decided negative angle of incidence, lessens the ship's tendency to dive — in a glide it will constantly nose up. With a longer fuselage I can use a smaller tail surface, so that will partly compensate for the weight of the boom.'

Jimmy entered the ship in the contest, flew it for 160

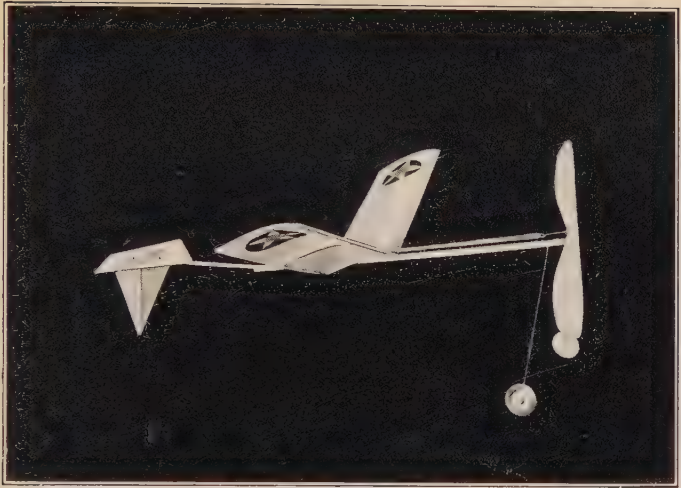
seconds, and won, hands down. The reason was that he had taken down his textbooks, figured out aerodynamical advantages, and incorporated them in the plane.

Jimmy Shields started his work with his motor stick or fuselage. The stick itself — the 'body' of the model — he selected of firm, straight-grained balsa. He sanded it down to size, taking extra precautions to make it exactly uniform throughout its length. Experience had taught him to do that.

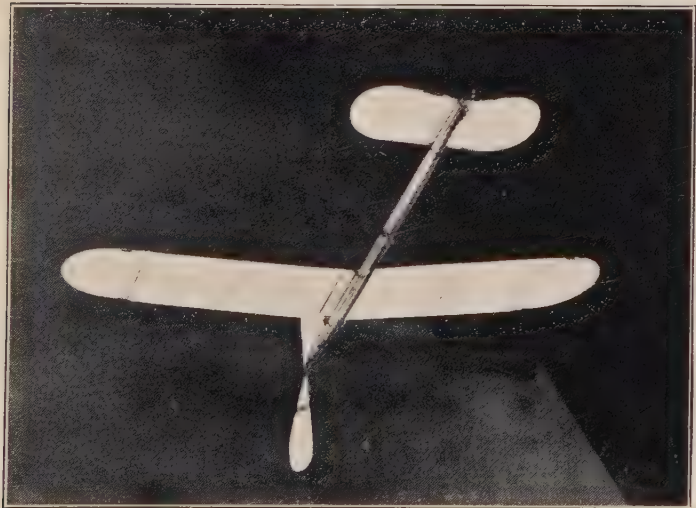
'A motor stick that's a tiny bit thinner in one place than in another,' he knew, 'is weak. It's likely to bend when the motor is wound, or to break, or to twist.'

His motor stick completed, Jimmy glued on the wire parts. The rear hook shown in the drawing goes directly through the motor stick and is bent back for security. The can is of the open-side type, like those used on outdoor models — it is glued on one side of the motor stick, but leaves a small opening at the other side. The thrust bearing is of half-round metal, bent and drilled for the propeller shaft. A flattened brad can be made into a satisfactory thrust bearing; sometimes a fairly heavy music wire is used, though this hasn't the strength to take a lot of pull from the motor.

The landing-gear Jimmy made of music wire, without axle. It is bent to shape and glued onto the motor stick. The wheels are made from circles of $1/32''$ flat balsa — their diameter is $3/4''$ and the inner circle is $1/16''$. The center section is $1/16''$ wide, and is carefully bored at the exact center for the wire hub. The two semicircles are cut out before the outside circle is cut, to avoid splitting



SENIOR R.O.G.



THE INDOOR PUSHER IN THE AIR

the wood. An extremely sharp knife is necessary for this.

To hold the wheels in place, Jimmy cut four $1/16''$ pieces of very thin balsa and cemented them onto the wire hubs, one inside each wheel, one outside.

Now the tail group:

As already pointed out, Jimmy made the tail surface relatively small, because of the over-all length of the ship. The drawings show the dimensions. The best way to construct it is to sand the tail boom and crosspiece exactly to size, then mark the center of the crosspiece and a point $1''$ from the rear of the tail boom and cement them together, the crosspiece above the boom.

The thread outline, of very fine silk, comes next. Glue one end of the thread to the boom at a point $1\ 3/4''$ in front of the crosspiece, then pass the thread around the ends of the crosspiece and the rear of the boom, cementing it at all points. It should be tight, but must not strain the balsa pieces.

The fin upright is glued to the boom at its intersection with the crosspiece, exactly perpendicular. A thread outline is used here, also; follow dimensions on the drawing.

Then apply the tissue paper — stabilizer first. Lay the tissue flat on top of the frame, and cement it in position, making sure it is stretched as tight as possible, without wrinkles. Allow it to dry, then trim it close with a sharp razor blade. Follow the same procedure with the fin — Jimmy put his paper on the right side of the fin, looking at the ship from the front.

Now, study the assembly of motor stick and tail boom

carefully. You'll see that Jimmy figured it pretty closely. The boom is set at a 4-degree horizontal angle, to cause the ship to circle to the left; and it is set at a vertical angle which brings the rear end $5/8''$ higher than the front end. Thus Jimmy gained that automatic stability. Cement the front end of the boom to the motor stick, just behind the rear hook. You'll need to sand the end of the motor stick off at an angle, to set the boom at that 4-degree pitch to the left.

And that's the motor stick.

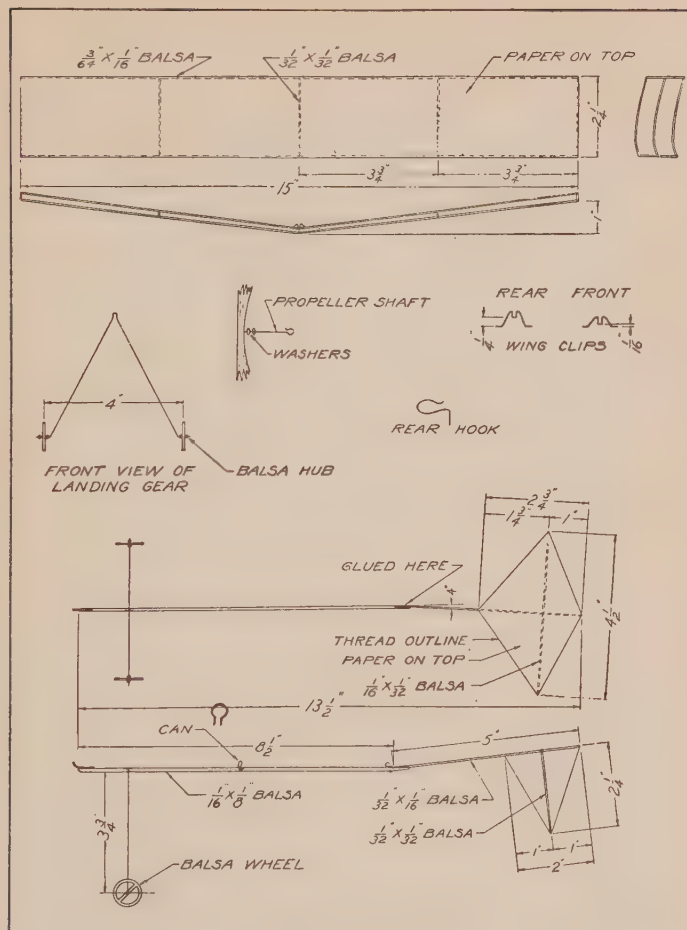
Jimmy used a cambered wing on his ship — that was another advantage. You League members who know your aerodynamics know that there is more lift to a cambered than to a flat wing. Any textbook will tell you the whole story, and it's worth knowing.

The drawing shows just how the Senior R.O.G. wing is made, and with the instructions found in Chapter VIII, you should have little if any difficulty in its construction.

Now carve the propeller. It is made from a block $5/8'' \times 3/4'' \times 7\ 1/2''$ according to directions found in the chapter on Propeller Design.

If you've followed Jimmy's plans carefully, you'll have completed the parts of an excellent little ship — one that weighs only .07 of an ounce. Jimmy found his motor stick, landing-gear, and tail group to weigh .025 of an ounce; propeller shaft and washers, .008; wing, .017; and rubber motor, .022.

You're ready, now, to hook all the parts together. Knot the 16'' rubber, insert the propeller shaft through the thrust bearing with the washers in place, and hook



NO. 18. SENIOR R.O.G.

up the motor. Attach the wing, and try gliding the model. If it dives, move the wing forward a little; if it stalls, move the wing back. When you've found the position for an easy glide, wind the motor a little and sail the ship off.

CHAPTER XI

INDOOR PUSHER

IN the early days of aviation, most of the big ships were of the pusher type. Before long, however, this kind became extremely unpopular with aviators, because in a crash the engine, which was situated behind the cockpit, had the unpleasant habit of breaking loose from its moorings, sliding forward, and crushing the pilot. Model-builders share the aviator's prejudice against the pusher.

'It doesn't look like a real ship,' they say.

Maybe not, but it can fly! The Mulvihill outdoor trophy — the official national trophy for duration — has been won *five times with a pusher, and only once with a tractor*. The pusher is not only a steady, reliable performer in the air, but it is simple and easy to construct.

Although you may substitute white pine for balsa in any of the wood parts, remember that white pine is heavier and will reduce the flying time of your plane. Balsa is the ideal wood because it is one half lighter than cork — and it is strong.

Before you start actual construction, study the drawing (No. 19). Many of you will be able to build your planes from the drawing alone, without the help of the text. The drawings show the assembled plane, and its five major parts, including the elevator, wing, motor stick, fin, and propeller. Whenever you get stuck on any part, study its diagram.

Figure II shows two views of the wing; one from the top and one from the side. Notice that it has a span of 16 1/2" and a chord of 3". Note that it has spars of balsa, tips and ribs of bamboo, and wing surfaces of Japanese imperial tissue. If you substitute white pine or basswood for balsa, you will want to finish the spars to about one half the size shown in the drawing, so as to save weight. See Chapter VIII for wing-construction details.

To hold your wing in place upon the motor stick, stretch a rubber band across the center of the wing and then push the motor stick through the two end loops of the band, underneath the wing, and the stick will be held tightly against the under side of the wing, as shown in Figure I. Later, when ready for your trial flight, you may want to move the wing backward or forward, to stabilize the plane.

Figure III shows you the motor stick with the rudder, or fin, attached. The same drawing shows you how to bend the front hook from .020 music wire. You will have to get this hook just the right shape by experimenting. Cement it to the front end of the motor stick (in the drawing this is the left end) as shown in Figure III. Your rear bearing is the small flattened brad with a hole large enough to receive the propeller shaft drilled through it. In the small drawing between Figures I and III this brad is called the thrust bearing. It is glued to the rear end of the motor stick (in the drawing this is the right end) as shown in Figure III.

The can, bent from .016 music wire, is clearly shown in

INDOOR PUSHER

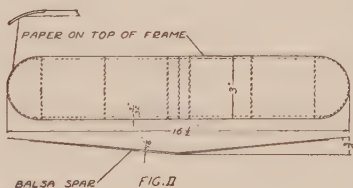
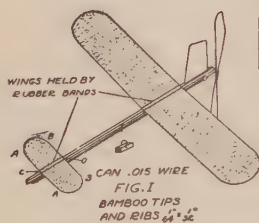
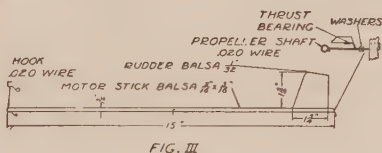
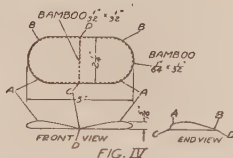
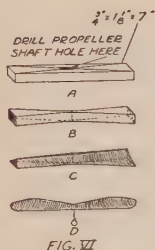


Figure I and it is glued to the center of the motor stick as shown.

At the rear end of the motor stick is the fin. This is made from a flat piece of balsa wood $1/32''$ thick. It is glued vertically to the top of the motor stick, as shown in Figure III. You may vary the shape and dimensions to suit yourself, although you should keep it approximately $1\ 3/4''$ high and $1\ 3/4''$ wide. Be sure, too, that it is vertical. If it isn't, it will interfere with the performance of the plane.

The elevator, shown in Figure IV, is probably the hardest part of the plane to construct; and it is just about the most important. Study not only the three drawings showing the top, front, and side, but the photographs, as well. Note, in Figure I, how it goes on the front end of the motor stick. Your study will show you that the front or leading edge of the elevator is $5/16''$ higher at the tips marked *A* than the rear or trailing edge marked *B*, except at the center where it rests on the stick marked *C* and *D*. Do you get the idea?

Finish the bamboo for the frame of the elevator to $1/16''$ square. Perhaps the best method of shaping it is to bend the strip to form one half the elevator. In the top drawing, Figure IV, this would be either the right or left half. Bend the strip over an open flame, just as you did the wing tips.

After the half has been bent to the proper shape, you can split it into two pieces. With a razor blade start first at one end, then the other, splitting it toward the middle (see Figure V). When these halves have been trimmed to

$1/32''$ square and well sanded, the corresponding ends can be cemented together. While gluing the halves together, the center rib may also be cemented in place. It is a good idea to put a small block under the point *A* while the cement is drying to keep the frame from rolling, and be sure to see that the trailing edge *BDB* is flat on the table.

Now, referring to the drawing, the leading edge, marked *ACA*, must be bent to form a flat 'V,' the point *A* being $5/16''$ higher than the point *C*. The trailing edge marked *BDB* is perfectly flat. This can be done by heating and beginning the bend at point *B* (see the end view Figure IV), until the point *A* is $5/16''$ higher when the side *DB* is laid flat on the table. Now heating the point *A*, bend it gradually till point *C* touches the table again.

Next the frame is covered with tissue. This is done in the same manner as used in covering the wing.

The elevator is held in place on the front end of the motor stick with a rubber band, just as the wings are.

The propeller for this model is carved from a balsa block $3/4'' \times 1\ 1/8'' \times 7''$.

Your power is obtained from a strand of $1/8''$ flat rubber 30'' long. The two ends of this are tied to form a fifteen-inch band, one end of which is hooked over the end of the propeller shaft and the other end with the knot over the front hook. The strands pass through the can. The rubber motor should be long enough to allow about an inch of slack when it is hooked in place.

You are ready to try your plane. Remember that it flies with the small end — the elevator end — to the

front. Give the propeller about three hundred turns and let the plane sail from your hands. If it misbehaves badly, you've probably been careless in finishing your parts to the correct dimensions. Perhaps you have not set your fin correctly upon the motor stick. Maybe your elevator doesn't have enough lift. In that case, you will want to build another, profiting by your experience and working more carefully. If your plane climbs too rapidly, set the wing back toward the propeller. If it climbs too slowly, set the wing forward. Once you have the proper adjustment, your ship will give you a smooth, steady flight that will delight you and astonish your friends. If the plane has a tendency to climb sharply and stall, turn and dive, regaining flying speed only to climb again to a stall; repeating this until the rubber unwinds, it can be made to fly smoothly by giving the wing a negative angle of incidence. This can be done by using a wing clip similar to the one described in the Baby R.O.G. directions. The leading edge should be held about $1/4''$ lower than the trailing edge. A small balsa block with a notch cut in the center to fit over the fuselage stick will also serve nicely.

CHAPTER XII

INDOOR ENDURANCE TRACTOR

OF all types of model airplane the indoor tractor is probably the most popular. You will find that, although it is a little more difficult to build and possibly a little more tricky to fly than either the Baby R.O.G. or the Indoor Pusher, it cannot be beaten when once adjusted properly and flying. You who have successfully built the two planes mentioned above will have no trouble in constructing this plane. If you haven't made the other two, it would be very advisable to construct them before attempting the endurance tractor.

This is the plane to build for demonstrations or to enter in the indoor contests. It was with a plane built from the plans below that Aram Abgarian established a new world's record of 207 minutes for indoor models.

White pine, basswood, or other very light woods may be substituted for balsa parts. If you are planning on entering a contest, this is not advisable, as balsa wood is much lighter than any other wood, and therefore increases the flying time of the plane.

Before starting to build the plane, be sure to study the drawing (No. 20) so that you have a definite picture of how your finished plane should look when completed, as much time will be saved and better results obtained if mistakes are prevented instead of corrected. Figure I shows the completed plane ready to fly, with all the parts in place, and

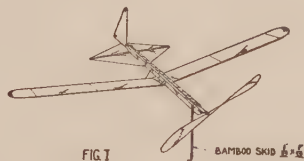
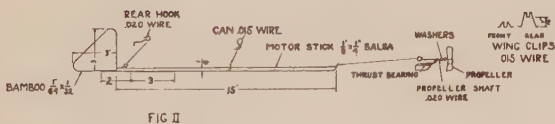
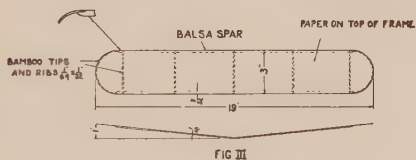
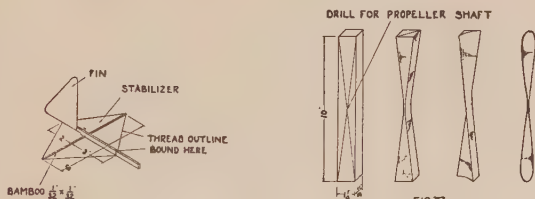
should be referred to each time before starting any of the details. By doing this you will prevent many mistakes and the parts of your completed plane will fit together better when finished.

The motor stick and tail group are shown in Figure II. Your motor stick should be straight, well sanded, and when finished not over $1/8'' \times 1/4'' \times 15''$. When the work is done carefully, this size may be reduced to $3/32'' \times 3/16'' \times 15''$, but in that case, if the stick is not almost perfectly made, it will break under the strain of the motor when wound. For this reason it is not advisable to reduce the sizes shown in the drawing, except for contest models. Expert model-builders use micro-meters to measure the thickness of the motor stick in order to get it uniform; in this way they can check it for size within one thousandth of an inch. If any other wood is substituted for balsa, the stick can be made much smaller, but will still weigh much more.

Remember that you are building this plane for endurance and that weight cuts down duration. If you can remove any surplus wood without weakening the parts, you have increased your duration. Tapering the stick toward the ends on the top and bottom and pointing the front of the stick under the thrust bearing are methods used by some boys. These little kinks may seem trivial and not worth while, but often are all that stand between the winner and the loser.

You can now fasten in place the metal parts, thrust bearing, rear hook, and can, as shown in the drawing. The thrust bearing is made from a small flattened brad.

INDOOR ENDURANCE TRACTOR



You can flatten a $3/4''$ brad by laying it on a flat piece of steel or iron and tapping it with a hammer. Do not flatten the brad any thinner than a $1/32''$ thick, or it will bend. Now you can drill a small hole in the end using a Number 76 drill for the propeller shaft. When drilled, the bearing should be bent as shown in the drawing, being very careful not to break it while bending. The angle of the bend must not be too sharp, as this weakens the thrust bearing and allows the propeller to rub against it when turning. The hole for the propeller shaft when in place on the motor stick should never be over $1/4''$ from the stick, just high enough to allow the rubber to unwind without rubbing against the stick.

Now you are ready to make the rear hook. This must be made of music wire, .020 being preferred; any other wire will bend under the strain of the rubber or if strong enough will weigh far too much to be considered. A pair of round nose pliers will be found handy in making the hook. You will notice how the end is bent over the rear end of the motor stick in order to give it a firmer hold. When you are bending your hook, be sure to make it so that it will lie close to the stick, just far enough away so that your rubber will not rub. If you have a high thrust bearing and rear hook, the rubber will bend the motor stick and possibly break it; if you make them too low, your rubber will not unwind freely.

The can is made of .016 music wire and should be made as shown in the drawing. The diameter of the loop should be about $1/4''$ and placed so that it will just clear the rubber on all sides when wound. These parts can now

be cemented in place on the motor stick in the position shown in Figure II. When you use airplane cement, binding with thread is not necessary, as the cement will hold the metal so firmly that the wood will break before the fittings pull off.

While the cement is drying, we can get the parts made for the tail group. If your paper is at all wrinkled, you had better iron it out flat before you start on any other parts, as you will want to let it stand a couple of hours after ironing, so that it will regain moisture. Otherwise it will warp your surfaces all out of shape.

The detail drawing of the fin and elevator, shown at the left-hand side of the drawing above the rear end of the motor stick, shows how these parts are made and assembled. In a full-sized airplane we have a fixed vertical fin, and fastened on this by means of a hinge is the rudder. The fin gives stability in flight, while the rudder gives directional control exactly as in a boat. In our model, we have only a fin, but curve this slightly when completed to take the place of a rudder. It is composed of a triangular bamboo frame covered with Japanese tissue.

Now then let's bend the fin. This is bent from a piece of bamboo $1/32'' \times 1/16'' \times 11''$. An easy way to get the shape you wish is by first drawing it on a piece of paper and then bending it to fit the drawing. The base and height of the fin should be three inches. The shape may be varied to suit your own ideas. Of the numerous shapes tried out, the one in the drawing has proved most satisfactory because of its strength and the ease with which it may be warped. The finished frame should form

a triangle with the base at right angles to the vertical or front side and should extend $1/2''$ under the rear end of the motor stick in a groove cut to receive it. Note in the drawing how the motor stick has been cut away to allow the base of the fin and the under side of the motor stick to form a straight line. Your fin is now ready to be split. You are probably wondering why we didn't finish the piece to size before bending. There are several reasons for this: first, bamboo is less likely to crack or bend sharply when larger pieces are used; second, the small pieces are more apt to char and spoil the piece, and finally, many boys bend up large pieces, and then whenever they need an extra fin all they have to do is to split one off. The fin when finished should be $1/64'' \times 1/32''$ thick, but it is wise to split the piece at least $1/32''$ wide and then work it down to size.

Many model-builders raise the rear end of the fin about $1/16''$ to set it at an angle to the motor stick, in order to give a negative angle to the stabilizer which is fastened to the fin. This they claim gives the model a better glide and helps it in flying. I should not advise any except experienced model-builders to try this, as some of the best records have been made without any angle at all on the stabilizer.

The best way to line up the fin with the motor stick is to cement it in place and then lay it on a flat surface, such as a table-top. With a tri-square set on end, you can check the fin as to whether or not it is perpendicular to the table.

While you are waiting for the fin to dry, you can finish

the propeller blocks to size and draw your lines on the top and bottom as shown in Figure IV.

When this is done, you can finish the tail group, as the fin will be dry enough to work on. The stabilizer (see Figure II) is a four-sided figure formed by stretching a thread from the base of the fin around the ends of a bamboo rib and back to the motor stick, where it is fastened in place. This frame is covered with Japanese imperial tissue.

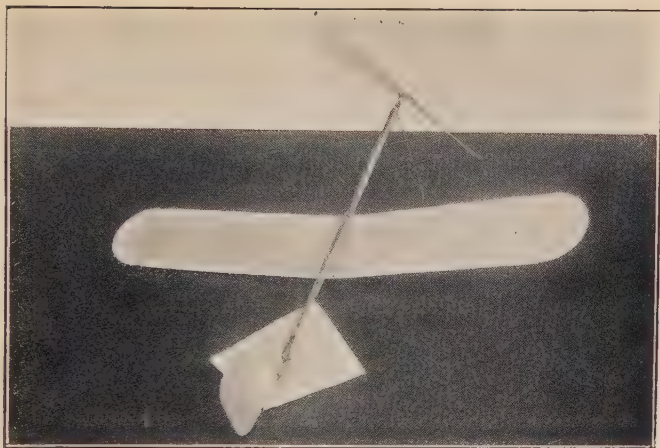
Your rib or cross-member should be split from a piece of bamboo six inches long to $1/32''$ square, making sure that the piece is perfectly straight and uniform the entire length or your plane will not fly smoothly. If you have trouble with the first one, try another, and you'll find that it isn't so hard after all. When this piece is finished, it is cemented to the under side of the motor stick. You should study Figure II carefully; notice how this stick is set in a notch cut $3/4''$ from the end of the motor stick so that the under sides of both sticks are exactly flush or even. This allows your stabilizers to lie perfectly flat.

The thread outline should be put on next. Here's the way it is done. A piece of thread $20''$ long is tied to the base of the fin $2''$ back of the cross-member so that the loose ends will be each about $10''$ long and the knot will be on the under side of the fin. Now you can stretch these ends out around the end of the cross-member — not too tight, but tight enough to prevent any slack. Then tie the end to the motor stick $3''$ in front of the cross-member, passing the thread under the motor stick and then over so that the thread will run to the under side. This

allows the whole outline to lie flat with the bottom of the motor stick. To hold your thread in position, paint the points of contact with cement.

Now paint the whole outline, fin, and motor stick with acetone cement dope. This strengthens the stick and helps to stick the paper to the frame. While this is drying, you can cut out your paper for the fin and stabilizer. This should be cut to about $1/2''$ larger than the surface to be covered, to allow for trimming. Next give your fin a coat of cement, wipe off, and lay the paper flat on the fin, holding the stick in your hand with the fin in a horizontal position. You shouldn't have any trouble with this operation, as the surface to be covered is so small that the paper seldom wrinkles. When the dope is dry, trim the paper close to the frame, either by rubbing with fine sandpaper or cutting with a razor blade. The next job is the covering of the stabilizer. First you paint with banana oil the entire thread outline, including the cross-member and the parts of the fin and motor stick which touch the paper. Now, holding the motor stick upside down, lay your paper in place, making sure there are no more wrinkles. When dry, trim it carefully with a razor blade, leaving at least $1/32''$ of paper on the outside of the thread. Never fold the paper over the thread, but leave the edge as it is cut. If you have a metal-edged rule, it will help you to guide the razor blade in a straight line. Another coat of dope around the edges of the paper will fasten all rough edges to the frame and completes the job.

You are now ready to start your wing. Figure I shows how this fits to the motor stick by means of wing clips,



LOOKING AT AN INDOOR TRACTOR FROM THE REAR



CULVER INDOOR TRACTOR

and Figure III shows a detail drawing with all dimensions.

If you need help in making this wing, refer to Chapter VIII, 'Construction Details.'

The assembled plane (Figure I) shows a bamboo skid fastened to the front of the motor stick. You will not need any directions for making this, as it is very easily seen how it is made. This skid is not necessary, but when used it protects the propeller and also helps to ensure stability. This completes the plane.

And now the fun begins. The rubber motor is a $1/8''$ rubber strand with the ends tied in a square knot to form a $15''$ rubber band. If a winder is used, we add a small 'S' hook to hook the rubber to the winder, and, when wound to the hook, the rubber is placed so that the knot will be at the rear hook and, passing through the can, is hooked to the propeller shaft. Before winding, let the plane glide from your hand to the floor. If it tries to climb and settles back on the tail, move the wing back, if it dives to the floor, move the wing forward; when it glides evenly it is ready to wind.

To launch the plane you should hold it in your right hand by the motor stick and with the left hand prevent the propeller from turning. When you are ready, release the propeller with your left hand and the plane with your right. If you have followed directions carefully, the plane will soar up, climbing rapidly in circles until it reaches its ceiling, where it will continue to circle until unwound, and then it will glide in large circles back to the floor.

If the plane makes too large a circle or flies in a straight

line, bend the rear end of the fin slightly in the opposite direction to that in which your propeller turns. This may be done by holding it close to your mouth and breathing on it while you curve it slightly with your fingers.

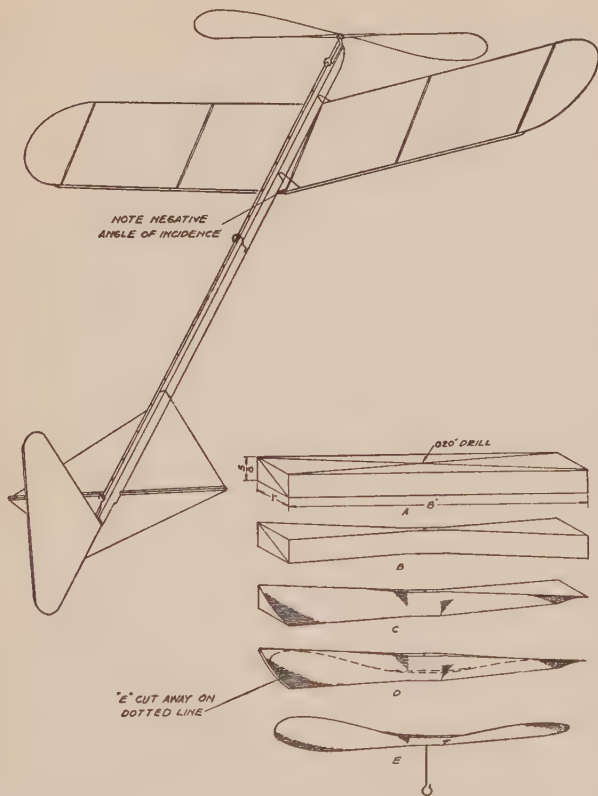
Remember that this plane when properly constructed will be so light that it will not injure itself when bumping the wall or any other object; and that this plane has twice won the National Indoor Trophy as well as breaking the world record for indoor flying by making a sustained flight of 207 seconds.

If you've built your tractor according to directions, you have a plane that flies smoothly and well. Probably you've timed it — have found that it will fly two minutes or more. If you have done as well as that, you can perform all sorts of interesting stunts with your tractor.

Now you have a tractor that will rise slowly in large circles until it reaches a height of fifty feet or more, and will then come down slowly to a perfect landing. Here are the things you can do with a tractor like that:

1. You can turn it into a pusher that should fly from sixty to seventy-five seconds.
2. You can try it out for altitude as well as duration.
3. You can determine its speed and the distance it will travel.
4. You can make it loop-the-loop, turn in short circles or fly straight, or you can build a landing-gear so that it can rise from the ground.

Turning your tractor into a pusher isn't hard at all. Just move your wing toward the propeller, wind your propeller *the other way*, and launch your pusher with the tail to the front! (Drawing No. 21.)

ENDURANCE TRACTOR FLOWN AS A PUSHER

NO. 21

It may not fly perfectly the first time. If it climbs too rapidly, set the wing back toward the propeller; if it climbs too slowly, set it forward. Give the propeller at least three hundred turns — to the left as you look toward the tail, remember — and your transformed indoor tractor will give your indoor pusher a contest!

Of course, the propeller on your tractor can't be expected to be as efficient as a pusher propeller. Its blades are cambered out a little, you recall, so that the propeller will get a better hold on the air as the edge cuts its way through. Naturally, when you wind up your propeller the other way, this 'camber' helps the air to slide off the blades — it's a hindrance instead of a help. So, if you want your tractor to perform as well as a pusher, you'll make a pusher propeller for it.

The propeller for the transformed tractor should be carved from a block $5/8'' \times 1'' \times 8''$ in size. When you have successfully flown your model with the 8'' propeller, try one carved from a $3/4'' \times 1\ 1/4'' \times 10''$ block.

Don't forget, when you put this pusher propeller on your transformed tractor, that it is a 'right-hand' propeller. That means that it must turn to the right to push your plane, and therefore you must turn it to the left to wind it. With this pusher propeller your improvised pusher should fly at least half as long as it will fly as a tractor.

If you restore the original propeller to your tractor, and reset the wing so that it will fly with the wing to the front once more, you can try out your tractor for altitude. A well-made tractor will spiral up to a hundred feet, if

you can find a building with a ceiling as high as that. It's fun to time the interval it takes your plane to get to the ceiling, just to find out what its climbing ability is.

Even though your tractor flies in a circle, it is not hard to find out how far it will fly. Suppose you have the fin set so that your plane will fly in a circle with an average diameter of thirty feet. (A good model will follow the same path around and around.) If the diameter is thirty feet, then the circumference is 30×3.1416 (pi), or 94.25 feet. Now time your tractor during several flights, until you have a good average figure representing the number of seconds your model takes to fly once around its circle. Now, knowing the distance represented by the circle and the time required to fly it, you can find the 'feet per second' speed of your plane. Once you have done that, all you have to do to find the distance your model will fly is to multiply the number of seconds it stays in the air by the number representing the speed.

For example, suppose your tractor flies around a circle 30 feet in diameter in 15 seconds. That means it is traveling about 95 feet in 15 seconds, a rate of $6 \frac{1}{3}$ feet a second. Now suppose your tractor stays in the air 120 seconds. To get the distance it flies, multiply 120 by $6 \frac{1}{3}$, and you get 760, the number of feet the model flies.

As for making your tractor loop-the-loop, you can do that by putting the wing far forward and winding up your rubber until you have a double row of knots. If you have enough motor power — perhaps you will have to add a double strand of rubber to your motor — your

ship will climb steeply, turn over on its back, and describe a pretty loop!

By experimenting with wash-in and wash-out on the wings, you can make your tractor fly right or left or straight, although you may need to warp the fin to help. (You have already learned that by bending up the leading edge at one tip, you give that side of the wing 'wash-in,' and by bending down the leading edge on the other tip, you give that side 'wash-out.' You can do this wing-twisting with your fingers, without heat. It helps to control the direction in which your plane flies!)

Then, if you like, you can make a landing-gear of two pieces of bamboo, $1/32''$ square and long enough to keep the propeller from touching the ground, cemented to the motor stick one on each side and slanting downward at an angle of sixty degrees from the horizontal. Another short piece of bamboo should be placed across these members, so that the whole structure looks like the capital letter 'A.' Now place two small L-shaped pieces of piano wire at the bottom of the uprights, cementing them so that two sections will project to form axles. Slip wheels over these axles, and then place a drop of cement on the ends of the axles to keep the wheels from coming off. Don't glue the wheels on. Naturally they will not turn if you do! (This method of constructing a landing-gear was diagrammed in Chapter IX, 'Baby R.O.G.')

CHAPTER XIII

THE MYSTERY TRACTOR

THE 'mystery tractor' was the next step in the development of the indoor endurance model described in Chapter XII. The credit should go to Ernest McCoy, a Detroit boy, although Aram Abgarian has succeeded in getting more out of the plane than any other model-builder. Aram, after the addition of a tail boom, obtained several flights of more than nine minutes and one of over ten minutes, while adjusting his plane before the 1930 National Contest. Let us get back to the 'mystery plane.'

The 'mystery ship' made its first appearance in the Michigan State Elimination Contest in June, 1928. It was christened 'The Mystery Ship' by the Detroit papers because of the care McCoy took to prevent any one except his helpers from seeing the model at close-up. As soon as the model landed, it was dropped into a black box and the lid locked. One cannot tell much about a plane when viewed from a distance of fifty feet, especially if the plane is in the air. McCoy won the contest with a flight of 271 seconds. Not so bad! — when you consider that the world's record was at that time 207 seconds.

Two weeks later, at the great Olympia Auditorium in Detroit, preliminary trials in the National Contest for the Stout Trophy began. Again McCoy led. His 'mystery ship' flew for 331.1 seconds — 5 1/2 minutes! McCoy

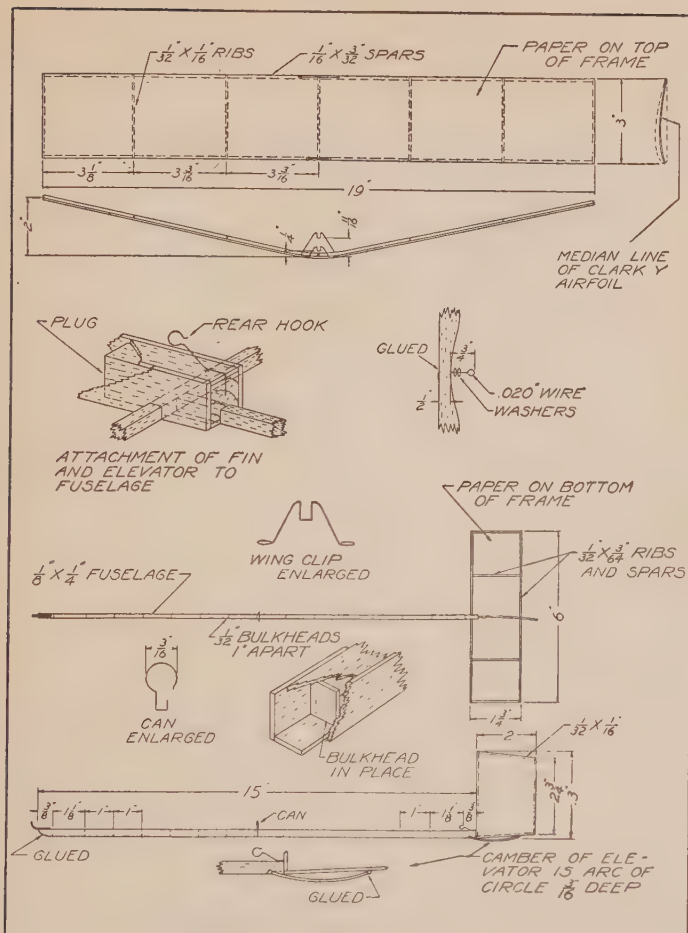
was no longer keeping it a mystery, though. Everybody watched and before long everybody discovered that, after all, part of the mystery was a cambered wing.

If you were one of the model enthusiasts who attended the contests, you'll remember how cambered wing models sprang up from every model box. It seemed as though fellows had cambered wings concealed in their vest pockets. The workroom was besieged with requests for balsa, paper — everything to make the McCoy model.

And that was where Aram Abgarian, Detroit boy, whose record of 287 seconds put him at the head of the junior division, came in. Abgarian had a new model ready for the finals — a model with a flat wing and tail, a built-up, hollow fuselage. The day before the finals he was practicing with this model in the Olympia. Bicycle riders were circling the board track. A bicycle swerved, but not far enough. The contest model — built-up motor stick and all — was a wreck.

It happened that Abgarian had a second motor stick of the same type. He went home, and got to work on it that night. All through the evening he pared and sanded and shaped ribs, wing spars, a paper-thin propeller. He built his wing with camber; he curved the tail surface upside down, as had McCoy. When six o'clock in the morning came, he was just finishing the model.

And that night, after he had competed in the outdoor contest at Selfridge Field, he took his new ship, gave its rubber motor 1200 turns — and flew it to a new world's record! It stayed up 353.6 seconds. Albert Mott, with a pusher and cambered wing and reverse camber elevator,



NO. 22. MYSTERY TRACTOR

took second, his plane flying 342 seconds. McCoy's record of 331.1 seconds won him third place.

Your hardest job is to make the built-up fuselage. Abgarian needed twelve hours for each of the two he built, so count on plenty of time for it.

The outside dimensions of the fuselage stick are $1/8'' \times 1/4'' \times 15''$. For its four walls you need four strips of balsa, $1/32''$ thick, $15''$ long. Two are cut $1/4''$ wide, the other two $1/16''$. Before they are cut they should be marked for plugs and bulkheads — the little inside reinforcements set at one-inch intervals.

First sand carefully a strip of $1/32''$ flat balsa, cutting it to the exact $15''$ length. Draw light pencil lines across the strip $3/8''$ from each end, $1\ 1/2''$ from each end, and at $1''$ intervals between these last two marks. Now you have located the thirteen bulkheads and the two end plugs.

Next, split the strip lengthwise — with a very sharp knife and a straight-edge — into the four side walls of the fuselage. Take one of the $1/16''$ strips and paint the two edges with cement, taking extra care not to get it on either face. Lay it flat on the table and stand the two $1/4''$ side walls up against it to form a square-cornered 'U.' If you have laid the strips properly, the pencil lines will correspond exactly; if they don't, some of the strips must be reversed, end for end.

Now with the end plugs and bulkheads, cut off two pieces $3/8''$ long, from the balsa strip $1/16'' \times 3/16'' \times 6''$ — the pieces you want, if your 'U' is properly made, will be exactly $1/16'' \times 3/16''$. Make sure that they fit

exactly — they must not bulge the ends — and then cement and set them in place. For the bulkheads, cut a strip $1/16''$ wide from the $1/32''$ flat balsa, then cut off pieces $3/16''$ long — thirteen of them, to be exact. Every piece must be precise — must fit neither too tightly nor too loosely. When they are finished and you have found them to fit *exactly* by setting them in place without glue, take them out one at a time, paint their edges lightly with cement, and reset them.

There must be room left on top of them, of course, so that the fourth side of the fuselage will fit in. Cement this in place, then sand the whole stick lightly to finish it. And you have a fuselage that is stiffer — less subject to twist by the wound motor — than a solid stick, yet lighter by the weight of the propeller. You save that much weight, and weight counts in an endurance model.

Now, paint the stick with cement at each end for added strength and set the thrust bearing and rear hook in place. Cement the can — an open or outdoor type to facilitate winding — in position.

You are ready now to build the tail group. The stabilizer is rectangular, hence slightly less efficient than a rounded-tip surface, but has an all-balsa frame, lighter than one employing bamboo tips. Both the fin and stabilizer are fastened to the fuselage by setting the connecting members into grooves cut into the end of the motor stick; the sketch in the lower left-hand corner of the diagram gives you the detail of this. Notice that the base of the fin is set at a light upward angle to permit the rear spar of the stabilizer to come up even with the front

spar — otherwise the whole tail would be set at a positive angle of incidence that would prevent the ship from climbing.

The fin is not hard to build. The drawing shows its dimensions. Its bottom spar is $2\frac{1}{2}$ " long, so that it can be set $\frac{1}{2}$ " into the motor-stick groove cut for it. Next the stabilizer. It has a reverse camber, you recall. Its ribs are all of balsa and you curve a piece $\frac{1}{32}$ " flat balsa, about $\frac{3}{8}$ " $\times$ 2" over a tea kettle's steam jet to make them. The curve is that of a perfect arc $\frac{3}{16}$ " deep. Once the piece is curved, cut it to the $1\frac{3}{4}$ " length and split it into five identical ribs. Make the two 6" spars, then assemble the frame, butt-joint the ribs to the spars. Cement the leading edge of the stabilizer into the groove, cut in the motor stick and the trailing edge to the base of the fin. Cover both fin and stabilizer (on the under side) with paper, and this part of the model is complete.

On the Abgarian model the wing was curved to the median line of a Clark *Y* airfoil. An exact template for this camber is given you opposite page 92. Using this as a model you can bend the ribs for your wing to the same curve. Perhaps, though, you'll want to use some different curve. McCoy used another camber and probably you'll find one to suit you. It is far from proved that the Clark *Y* is the best to be found.

This method of making and assembling the wing is much the same as that you used in building the stabilizer. Use extreme care to get it absolutely accurate. Probably you will want to bend the long piece from which the wing spars are to be cut before you split it — thus you will

get exactly the same degree of dihedral angle into both spars.

Abgarian has succeeded in improving the performance of his tractor by mounting the tail surface on an auxiliary tail boom. The method of mounting is similar to that used on the Senior R.O.G. and the Mott tractor. Either the solid stick boom or a hollow tube may be used.

Cover the wing, once the frame is completed, and cement the wing clips to it. It is wise to be sure that the clips fit the fuselage before you attach them, however. You'll save yourself some trouble. Your last job is to make the propeller. It is carved from a balsa block $1\frac{1}{2}'' \times 1\frac{1}{4}'' \times 12''$, an unusually large prop for this type of plane, hence one which must be made paper-thin. Chapter VIII gives you details of all the steps in its carving; also a photograph of the propeller which Abgarian used on his champion model. Don't forget that you want it to be the best-made prop you've ever completed — so thin, if it's properly done, that you can bend the blade backward and forward at least two inches without breaking it. Except at the hub it should never exceed $1/32''$ thickness.

For so large a propeller the plane must be exceptionally light. That means that there's no latitude for slipshod or 'nearly as good' work in the construction of the model. It might be a good idea for you to test your ship, when it's finished, with a ten-inch prop, if you have one available, so as to see how it performs. When it's properly adjusted, put on the longer prop.

Chapter VIII tells you just how to change the wing

setting if the ship climbs or dives, how to give the leading edge wash-in and wash-out, and other ways of improving its flight.

Don't be discouraged if it doesn't suit you the first time you try it. Perhaps the stabilizer angle is wrong; perhaps the prop isn't quite correctly balanced. By repeated trials you can doubtless find the difficulty.

CHAPTER XIV

THE CULVER INDOOR TRACTOR

JOE CULVER *knows* his airplane models. Culver is the Oakland, California, boy whose indoor airplane model made history at the Second National Airplane Model League of America Contests, in June, 1929. Climbing in steady, unvarying circles in the big Detroit Auditorium, it flew to the unheard-of record of 8 minutes, 33 seconds; it won for Culver the William B. Stout Trophy, cash prizes, a gold medal, a huge silver cup, and a trip to Europe offered by 'The American Boy,' organizer and sponsor of the League.

The best indoor airplane models in the world were in that contest. There were pushers and tractors, cambered and flat wing models; there were planes of a dozen designs. There were expert fliers, too: Aram Abgarian, ex-world's champion; Ernest McCoy, designer of the 'mystery ship' that served as a model for many of the planes; Albert Mott, second-place winner in 1928; Lawrence Hankammer, Edward Petruska, Glenn Reichman, Albert Schwarzkopf.

Look at the photograph of the model and the diagrams. Notice the curved wing in place of the conventional dihedral-angled surface; notice the shape and placing of the rudder, the long propeller, the form of the tail surface, the extra length. The tail group, you'll see, is on a boom

somewhat similar to that in the Senior R.O.G. The wing has no wash-in or wash-out.

All of these out-of-the-ordinary features Culver put there on purpose. The tail surface is slightly curved for more stability. The length of the tail boom means fore-and-aft balance. The 14" high-pitch propeller, slower motion, slower unwinding of the rubber.

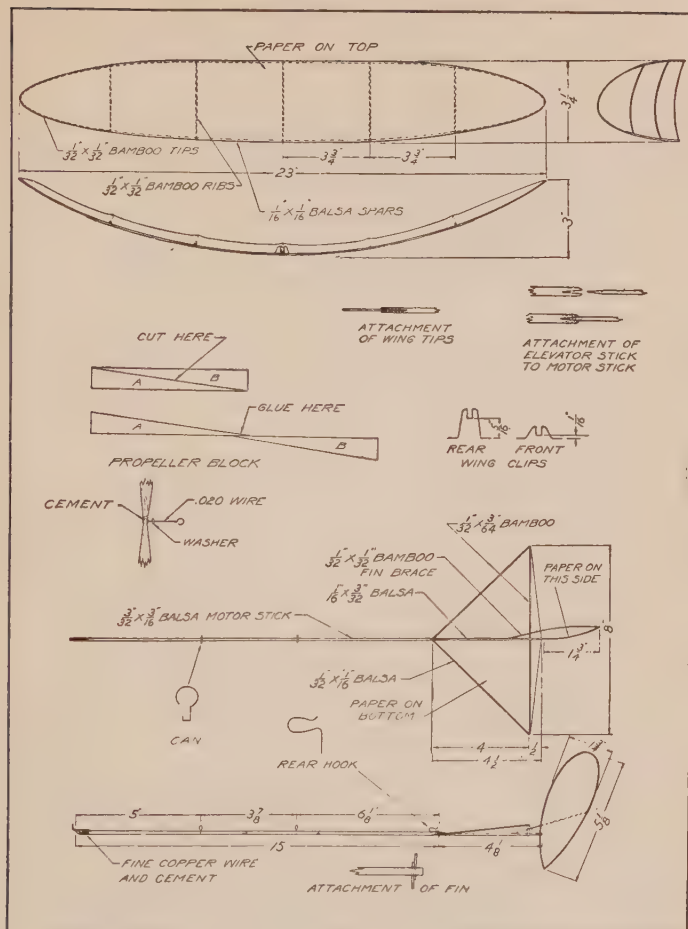
And the lack of wash-in and wash-out, a feature most airplane model-builders give to every ship they construct? Let Culver tell you why.

'This ship turns against the torque,' he points out. 'That is, its circle is clockwise rather than counter-clockwise. Thus it tends to bank with the right wing down. The propeller torque, however, tends to twist the ship in the opposite direction. Consequently, the two forces can be made to balance each other.

'This has several advantages. By eliminating wash-in and wash-out (necessary when a ship turns with the propeller torque), I decrease the drag; the ship offers less resistance to the air ahead of it. By turning against the torque, also, the ship can describe a circle of more constant radius than in the old method, which depended on torque, a variable quantity, for the turning effect.

'Fellows may not find this method satisfactory the first times they try it. Credit for it in Oakland goes to Herbie Owbridge, of the Mariposa Model Club; but it took us all, working together, a year to get it to suit us.

'As a matter of fact, lots of fellows prefer the other kind of ship. A chap ought to decide which type he likes best, then learn *everything* there is to know about it.'



NO. 23. CULVER CHAMPIONSHIP MODEL

You all know, from your previous model-building, that the first thing is to study photograph and drawings, and read the instructions carefully. Know exactly what you're going to do. When you have every step in mind —

Start work on your motor stick.

Culver used a hollow or built-up stick in his ship. The walls of the stick are of balsa sanded down to $1/32''$; the two side walls should be $3/16'' \times 15\ 1/4''$, the top and bottom $1/32'' \times 15\ 1/4''$. Interior bulkheads, spaced an inch apart, should be $1/32'' \times 1/16'' \times 1/8''$. Two end plugs, $1/32'' \times 1/8'' \times 1/2''$, close the ends of the tube. Extreme care must be taken with this job; the cementing must be carefully handled and the whole stick should be sanded smooth after the cement is dry.

Note that while the distance between the front of the stick and the rear hook is exactly $15''$, the stick protrudes $1/4''$ at the rear, for fastening the tail boom.

The boom or elevator stick is of balsa, $1/16'' \times 3/32'' \times 4\ 1/8''$. It tapers slightly to the rear, so that the rear end is $1/16''$ square. Culver attached it to his motor stick, as the drawing shows, by sanding the forward end into a 'V' and cementing it into a similar 'V' cut in the end of the stick.

The stabilizer crosspiece of $1/32'' \times 3/64'' \times 8\ 1/4''$ bamboo, is bent — over the steam jet from a tea kettle or over an open candle or gas flame — into an arc in which the ends are about $3/8''$ above the center. It is cemented flush into a groove cut in the boom $1/2''$ from the end. Two 'slivers' of balsa $1/16'' \times 1/32'' \times 5\ 5/8''$ are then cemented to join the ends of the bamboo cross-

piece and the motor stick. Now the whole stabilizer can be covered — on the bottom — with Japanese imperial tissue.

The rudder frame is of one piece of $1/32''$ square bamboo, $12''$ long. Bend the bamboo over steam or flame to a shape approximating that shown in the drawing — it isn't necessary to duplicate it exactly — and cement the ends together. Split the end of the tail boom and set the frame into the notch about $1/16''$; then cover the frame, on the side shown in the drawing, with paper.

Culver's final touch was a little strip of $1/32'' \times 1/32''$ bamboo labeled 'fin brace' on the drawing. By the use of this brace, cemented to the rear edge of the rudder and the tail boom, he warped the rudder to the right to make the plane circle against the torque. Moreover, by bending this brace slightly with his fingers after it was in place, he was able to increase or decrease the turning effect.

Culver used two open-side cans like those in the diagram and a rear hook protruding through the motor stick. The thrust bearing — a flattened, bent, and drilled brad — is cemented at the front and bound with two inches of silk thread for strength.

The wing has a 'curved dihedral.' The two balsa spars, $1/16'' \times 1/16''$ at the center and $13''$ long, are tapered slightly toward the ends, 'to put the wood where it was most needed,' explains Culver. The spars can be bent over heat — very little is needed.

The ribs are $1/32''$ square bamboo, curved into a perfect arc with the top of the arc $1/4''$ above the ends. The three center ribs are $3\ 5/16''$ long, the two nearest the

ends $2\frac{7}{8}$ ". Cement them in place, then bend $1/32$ " $\times$ $1/32$ " bamboo into elliptical tips and cement them. Note that the tips are set into notches in the spars, just as you set the tail boom into the motor stick.

Cover the completed wing frame with tissue, as described in the chapter on Construction Details, and add the wing clips, and this part of the job is complete.

The propeller is carved from a block $1" \times 1\frac{1}{4}" \times 7\frac{1}{4}"$. This is cut on the diagonal, as shown in chapter on 'Propeller Design,' to obtain the two halves which are then cemented at the center to form the completed propeller.

CHAPTER XV

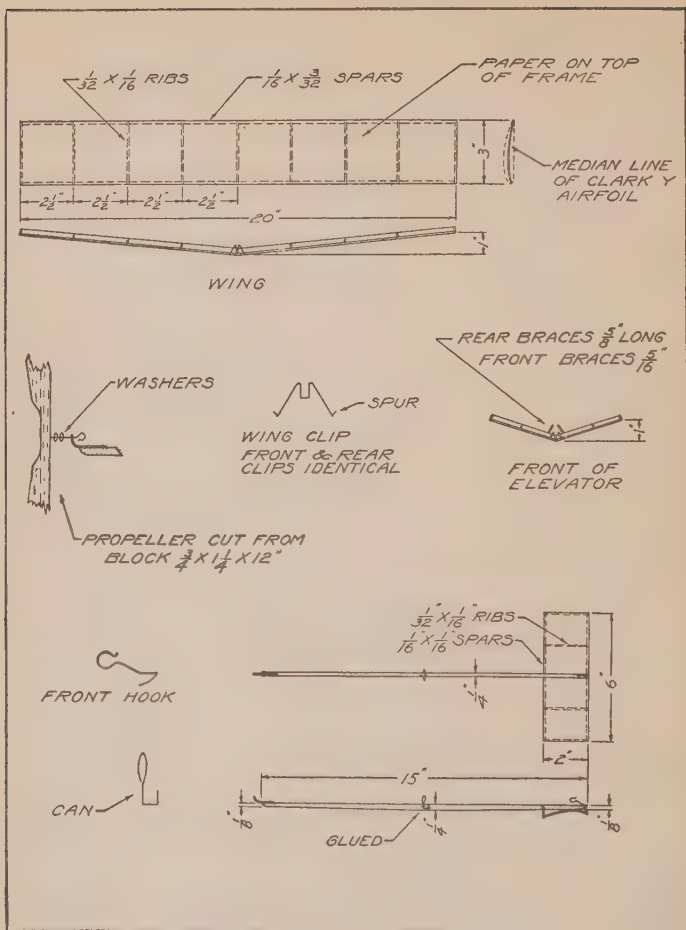
THE MOTT PUSHER AND TRACTOR

DRAWING 24 shows the Mott pusher used by Albert Mott in the 1928 A.M.L.A. National Contest. The plane not only won first place in the Senior Class, but established a world's record for indoor pushers which still stands. The plane is so much like the other indoor planes described in the book that it will need very little description. Remember, while carving your propeller to cut away the trailing edge instead of the leading edge as in the tractor.

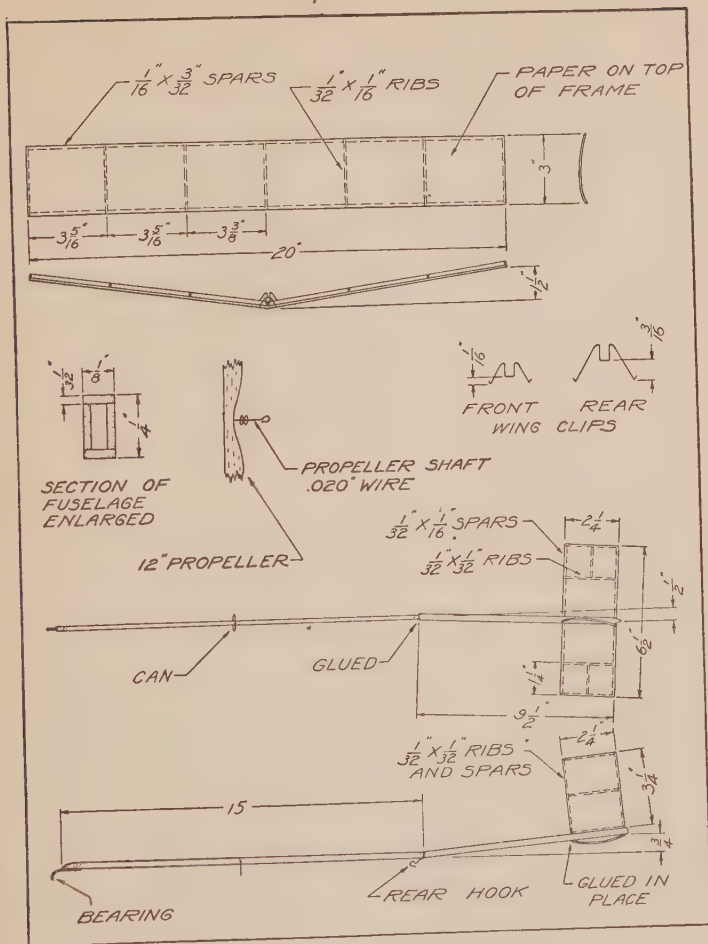
A solid balsa motor stick was used on the original model. A built-up stick may be used instead. Notice that both ends of the stick are cut away under the fittings; also that they are well painted with cement.

The elevator is set under the front end of the motor stick. The frame is made entirely of $1/16''$ square balsa. The ribs with a curve similar to the median line of the Clark Y section are of $1/32'' \times 1/16''$ balsa. Four balsa braces are used to attach the elevator to the stick. These are shown in the sketch of the elevator in the upper right-hand corner. The two rear braces are just twice as long as the front two in order to give the required angle of incidence. When in place, the braces are cemented to the stick.

The propeller is carved from a block $3/4'' \times 1 1/4'' \times 12''$, using the method described in the chapter on



NO. 24. MOTT INDOOR PUSHER

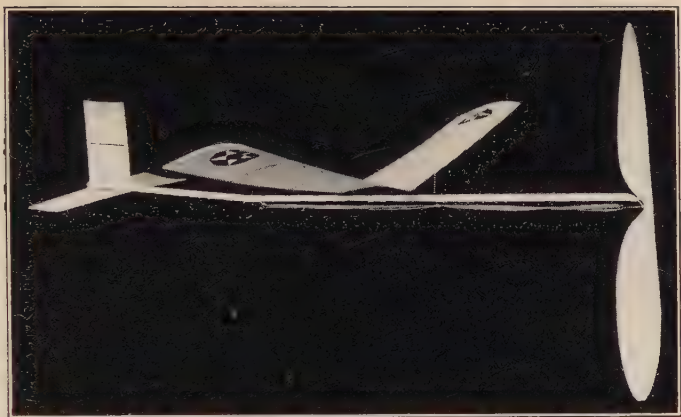


NO. 25. MOTT INDOOR TRACTOR

'Propellers.' The butter-paddle type of blade is used on this model.

The Mott tractor is almost identical with the 'mystery ship' in design, except for the hollow balsa tail boom. This is made by wrapping $1/64''$ balsa veneer around a $1/4''$ metal rod as described in Chapter VIII. Notice that the boom is set at an angle to the motor stick so as to give a permanent left rudder. It is also set so that the rear end is $3/4''$ higher than the motor stick. This gives the stabilizer a negative angle of incidence. In a glide the plane has a tendency to nose up.

The chief difference between the planes entered by Mott and Abgarian in the 1929 National Contest were found in the shape of the propellers. Mott is a firm advocate of the wide or butter-paddle type, while Abgarian clings to the long slender blade. The photographs of their propellers in the chapter on 'Propeller Design' shows the form of each. Abgarian gains efficiency by adding to the diameter where it is most effective and at the same time slows his R.P.M. up to a minimum. Mott slows his propeller up by increasing the width of the blades. This additional surface acts as a brake. Theoretically, Abgarian's method is best. Mott has the advantage of a greater ease in maintaining stability, making it much easier to fly. Only the experienced model-builder succeeds in flying the Abgarian ship with the great diameter propeller. Even Aram has to make a number of trial flights before he gets his extremely sensitive plane to fly properly. Both models have unofficial records of over ten minutes to their credit.



MOTT TRACTOR



CHAFFEE C-4 INDOOR CABIN FUSELAGE

A new world's indoor record has been established! Ray Thompson, of Detroit, has just flown his indoor tractor to win the Third National Contest and a trip to Europe in the unheard-of record of eleven minutes, fifty-seven seconds. As there isn't sufficient time to make drawings of this plane before going to press, we will have to content ourselves with a verbal description of it.

Thompson's plane differed very little from the Mott tractor. He had a slightly cambered wing, using round slightly $1/16''$ tapered Balsa spars and round $1/64''$ square Balsa tips. He used a hollow fuselage and a solid $1/16'' \times 1/8'' \times 8''$ Balsa tail boom. The tail boom was cemented to the end of the fuselage and parallel with it. A small square-tipped elevator, taped to the center and covered on the bottom, was cemented to the rudder and the end of the boom. The rudder was four-sided, the front upright being perpendicular to the tail boom, the rear one tapering toward the bottom. The spars of both the rudder and elevators were made of $3/64'' \times 1/32''$ square Balsa, the five ribs being of $1/32''$ square Balsa.

The major difference between Thompson's plane and others used in the Contest was in the design of the propeller. Thompson made his propeller in two halves as shown in the photograph on propeller carving. (Page 62.) Instead of joining the halves squarely as usual, he set them at an angle so as to give the propeller sweep-back; that is, the propeller hub was set $1\ 1/2''$ ahead of the rest of his blade. The block used was approximately $1'' \times 1\ 1/4'' \times 12''$. The finished propeller had a diameter of $1\ 3/4''$, the blades being $1/4''$ wide at the center and

1 $1/4''$ wide near the tips. Slightly rounded corners were the only change made in the shape after carving, except for the V at the center. This left the blades 1 $1/4''$ wide for a distance of 2 $3/8''$ at the tips. Full specifications on the plane are given below.

Wing

Spa, 21''.

Chord, 3 $1/2''$.

No taper.

Angle of incidence, $7/16''$.

Weight, .035 ounces.

Fuselage

Hollow tapered from ends to center.

Width, $1/8''$.

Width, $1/8''$.

Height, $1/8''$ at ends, $1/4''$ at center.

Length, 15 $1/2''$.

$1/16'' \times 1/8'' \times 8''$ tail boom overlaps rudder.

One half inch for joining.

Empennage

Elevator span, 6 $1/8''$.

Chord tip, $17/8''$.

Chord root (center), 2 $1/4''$.

Rudder, 2'' at base.

Rudder, $11/2''$ at top.

Height, 3''.

Weight of assembled fuselage and empennage, .034 ounce.

Propeller block, $1'' \times 1\frac{1}{4}'' \times 12''$.

Diameter, $11\frac{3}{4}''$.

Sweepback, $1\frac{1}{2}''$.

Weight assembly, .021 ounce.

Weight entire plane without rubber, .09 ounce.

CHAPTER XVI

CHAFFEE C-4 INDOOR FUSELAGE MODEL

THE C-4 shown in the accompanying photograph is one of the best indoor fuselage models, and because of its attractive appearance has become the favorite with model-builders. William Chaffee, 1926-27 World's Indoor Record holder, is the designer. The wing should be given a chord of not more than $3\frac{1}{8}$ " instead of $3\frac{1}{4}$ " as shown in the drawing. The N.A.A. classifications for model airplanes provide that a wing with 65 square inches or over belongs in Class C. If the C-4 is built with a wing area, just less than 65 square inches, it will belong to Class B. As it is right at the limit of Class B, it will have a much better chance to establish a record.

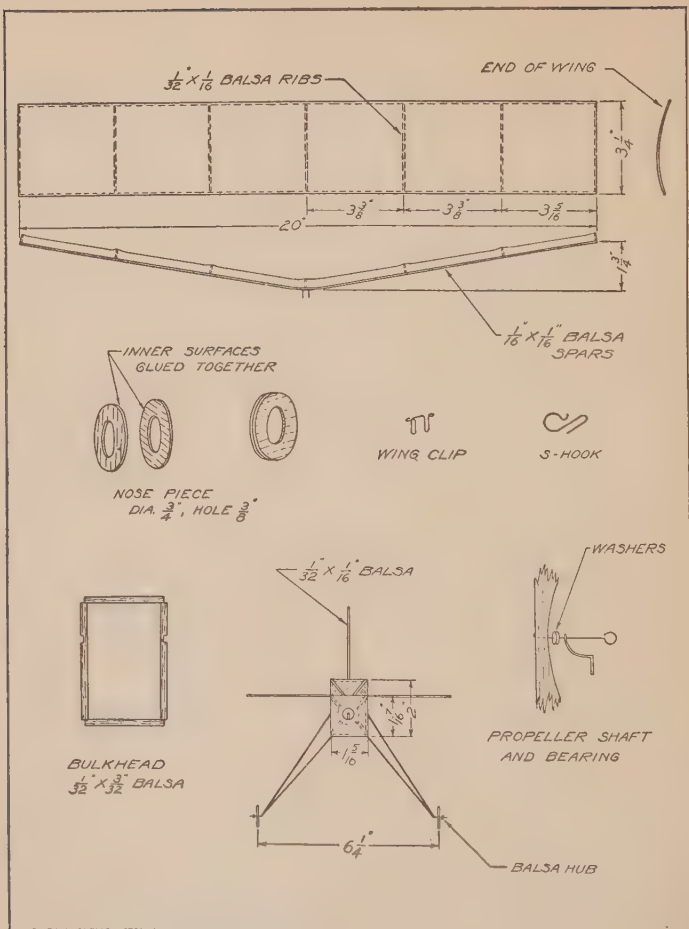
Before you start building, notice the snappy lines of the model. Study the diagrams and the photographs in detail; read these instructions thoroughly. Note, too, that the ship employs no motor stick. Instead, the fuselage construction is sturdy enough — though it is very light — to withstand the stress of the tightly wound motor.

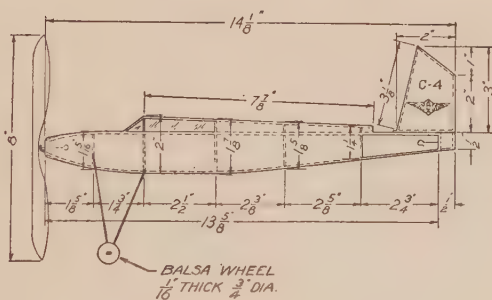
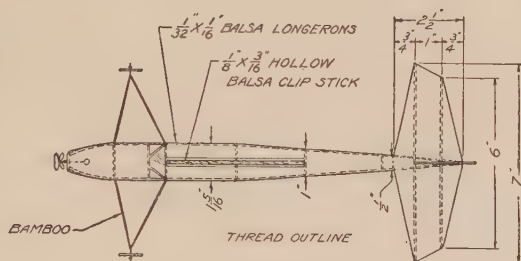
The A.M.L.A. has prepared a special kit for this model. These may be purchased from the League Promotion and Supply Division, 300 Davis Avenue, Dayton, Ohio. These kits simplify the construction of the model by providing heavy outline patterns over which the model can be made. All parts are cut to size.

Start with the fuselage. And to start the fuselage, make the five bulkheads first. These bulkheads are of varying sizes. For convenience it is better to number them on the diagram, in pencil, from front to rear — 1, 2, 3, 4, and 5. They are made of balsa strips $1/32'' \times 3/32''$ in cross-section and the dimensions and locations of each are shown in the diagrams. Make No. 1 first. The diagrams show you that it is $15/16''$ square; note, however, that the top and bottom members must be $1/16''$ short to allow $1/32''$ at each corner for the longerons. Moreover, the side members must be $3/16''$ short because the top and bottom members add $3/32''$ to each bulkhead size. For No. 1, therefore, you'll need two strips $11/4''$ long and two $11/8''$ long. Cement them carefully together.

The remaining bulkheads are made in the same manner, but must have grooves $1/16''$ long and $1/32''$ deep cut in the side members to take the longerons. In No. 2, cut these grooves just $1/2''$ below the top of the bulkhead; in No. 3, $3/8''$; in No. 4, $5/16''$, and in No. 5, $1/4''$. Lay the bulkheads flat on your work-table and cut the grooves out with a safety razor blade.

Make the nose piece from $1/32''$ flat balsa. First draw the two balsa washers, $3/4''$ in diameter. Cut out the center holes with a razor blade, or, better, with a hollow metal tube $3/8''$ in diameter (an empty cartridge shell is excellent for this), using it like a cooky cutter. Cut out the outer circles next and glue the two washers together so that the grain in the pieces runs at right angles. Finally cut out four right-angled grooves, two at the top





INDOOR FUSELAGE MODEL

$3/8''$ apart and two at the bottom $3/8''$ apart, in which you'll later set the ends of the four longerons. Sand the finished washer down smoothly and cement the thrust bearing to it — the shank of the bearing inside the washer, the curved part extending through the hole. You'll have to line up the hole in the bearing very carefully with the exact center of the washer. A square nose may be substituted for the round one shown in the drawing. This makes the construction and covering of the nose much easier.

The final vertical member of the fuselage is the rear post, a piece of balsa $3/32'' \times 1/8'' \times 1/2''$. The rear hook passes through this post and its end, bent into a 'U,' is embedded and cemented in place, just as you have learned to do with a propeller shaft.

Now the four main longerons. Cut these $1/32'' \times 1/16''$ balsa about $14\ 1/4''$ long. Cement all four to the nose-piece grooves, after marking on the upper pair the positions for bulkheads. Number 1 is placed $1\ 11/16''$ from the nose — $1/16''$ more than the diagram shows, to allow for the curve. The other four are spaced as the drawing shows. Cement No. 1 bulkhead to all four longerons, then cement 2, 3, 4, and 5 to the *upper longerons only*. When the cement is firm, finish this part of the job by cementing the lower longerons into place. Be very careful in doing this — the shape of your fuselage depends on your exactness. Now, trim off the rear ends of the longerons properly, and cement them to the rear post — two at the upper corners, two at the lower. This tapers the fuselage off.

The roof of the cabin and the top of the ship is formed by two shorter longerons $1/32'' \times 1/16'' \times 7\ 7/8''$. Cement them into the corner grooves in the four bulkheads; they will protrude 1 to 2 inches behind No. 5. Join their rear ends with $1/32'' \times 1/16''$ balsa cut to fit, and attach them to the upper main longerons with shorter $1/32'' \times 1/16''$ pieces, also cut to fit.

Chaffee used for his clip stick a hollow balsa spar — the walls are only $1/64''$ thick! He put in no bulkheads, as the stick suffers no twisting strain — its only purpose is to furnish a surface to which to clip the wing. You may use solid balsa if you wish — the advantage of the hollow stick is a slight decrease in weight. To make a hollow stick, follow the procedure you used in building the hollow fuselage stick in the Culver Endurance Model (described in the chapter on construction). It is butt-jointed to the upper members of bulkheads 2 and 4 with a groove cut from its upper surface to permit the upper member of bulkhead 3 to fit into it. When in place, its top surface is flush with the tops of the bulkheads. It is very important to have the clip stick uniform in thickness and perfectly rigid so that the wing clips will grip it properly. In flight it carries the weight of the ship.

The landing-gear is of bamboo $1/32''$ square. The two front struts are $4\ 3/8''$ long, the two rear $4\ 1/16''$. Cement them to the bulkheads as shown, at the same time cementing the lower ends together. The short wire axles, two pieces of .016 music wire bent to L-shape, are cemented to these ends.

Wheels are cut from $1/16''$ flat balsa. Since the N.A.A.

classification for R.O.G. planes in Class B provides for a wheel of not less than 1" in diameter, you had better increase the size of your wheel to conform to these requirements, if you plan on going out after records. Chaffee reinforced his wheels with small brass washers, one on each side of each wheel. Thus he formed hard bearing surfaces for the axles.

Finally, complete the front windows. Fit a balsa cross-piece between the two upper main longerons, $5/8''$ in front of No. 2 bulkhead. Cut two braces of the proper length; cement them into place with their forward ends at the crosspiece $7/16''$ inside each longeron and at the other ends to the junction of bulkhead 2 and the same longerons. Sloping up from the same points on the cross-piece, add two more strips with their upper ends at the corners of the bulkhead. (The first two strips do not show in the drawings — they are directly under the second pair out in the top view, and directly behind the upper main longerons in the side view.)

Cover the entire ship with Japanese tissue, with the exception of the three front small windows, the two side windows (between bulkheads 2 and 3), and the sides of the ship between bulkhead 5 and the rear post. With a safety razor blade cut away the paper above the clip stick, leaving $1/16''$ inch on each side so that the wing clips will fit in easily. The windows are covered with cellophane — the light glassy paper used on sanitary food packages. Use model airplane cement or banana oil as the adhesive.

Next, the stabilizer. Two $1/32'' \times 1/16''$ balsa spars,

one 6" and the other 7" long, are cemented into grooves cut in the upper main longerons. Use a thread outline around the spars to form the shape shown in the drawing and cover the whole with tissue.

Follow the drawings in making the rudder, using balsa strips of the same cross-section. It is a good idea to draw the shape of the rudder on paper, then fit the balsa strips exactly to the drawing. Make the rear edge $2\frac{1}{2}$ " long so that it protrudes $\frac{1}{2}$ " below the bottom member. Cement the frame into position attaching it to the two stabilizer crosspieces and the top of the rear post. It should be set at an angle so that its forward edge is $\frac{1}{16}$ " to $\frac{1}{8}$ " to the right of center. This will cause the plane, in flight, to circle to the left. Attach the bottom of the rear member to the rear post with a small strip of balsa, cut to fit. Then cover the frame on either side with tissue. The fuselage is finished, and the hardest part of the job is done.

Making the wings is an old story to model-builders. The wing ribs should be marked off on balsa $3\frac{1}{4}$ " wide ($3\frac{1}{8}$ " to keep the plane in Class B) and $\frac{1}{32}$ " thick, then bent in steam to the desired camber before splitting. The wing spars may be marked on balsa and bent to the right dihedral angle or they may be cut at the center and butt-jointed to form the angle. Note that though the over-all length of the angular wing is 20", each half is $10\frac{1}{16}$ "; therefore the full-length spar must be $20\frac{1}{8}$ ". Attach the two wing clips — they are identical — and apply the Japanese tissue covering on top. And that's the wing.

The propeller is carved from a block $5/8'' \times 1'' \times 8''$.

The motor is a strand of $1/8'' \times 30''$ rubber, 27 $1/2''$ long.

Now, clip on the wing, hook up motor to prop shaft — and the ship is ready for its maiden glide! A few trials will show you the best adjustment for the wing. Give the motor a few winds, and see how it behaves under power.

Have you been wondering about that 'winding hook' shown in the drawing? That's something new. And any fuselage model-builder who has had a nearly wound rubber motor snap inside his finished ship will see its virtue — for a breaking motor means a wrecked ship.

Two 'S' hooks are used with this model, one at each end of the motor. Remove the front hook from the prop shaft and catch it with the winding hook. Remove the rear 'S' hook and attach it to your egg-beater winder. Then, holding the winding hook handle, pull the motor from front to rear through the ship and catch the front 'S' hook with a pair of pliers. Now, stretch the rubber to three times its ordinary length (if you are an expert model-builder, you'll have rewound it a couple of times, six or seven hundred turns), and wind it 1000 to 1200 times. Attach the front 'S' hook to the winding hook again and pull the motor back through the fuselage. Catch the two 'S' hooks, one in the prop shaft and the other in the rear hook.

If your work has been careful, if the ship is adjusted properly, if the hall where you're flying is big enough, you ought to get a three-minute flight after half a dozen trials!

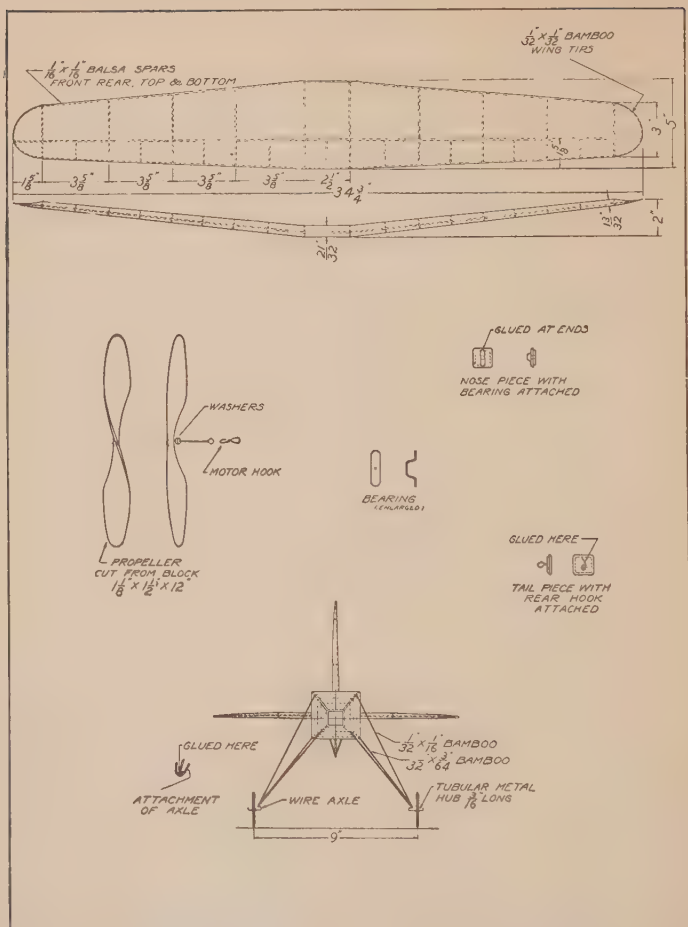
CHAPTER XVII

BURNHAM'S OUTDOOR FUSELAGE MODEL

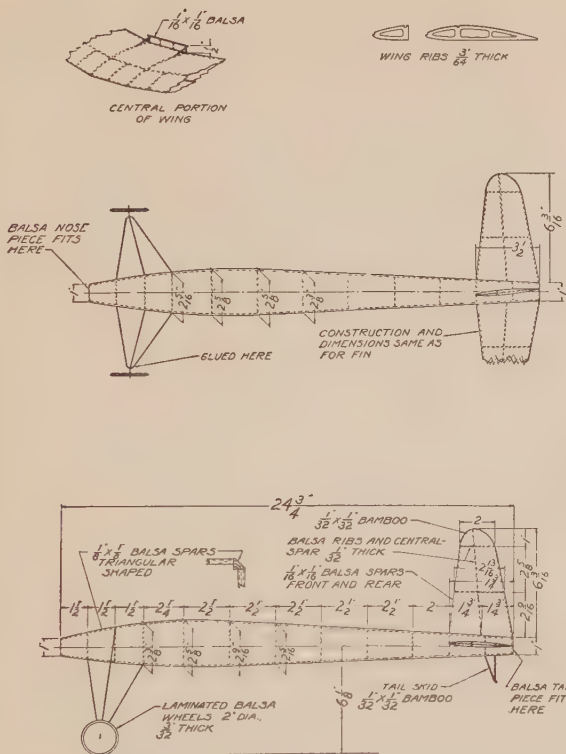
WHEN America's 1929 airplane model champions went to Europe as guests of 'The American Boy' and 'Aero Digest,' they found out that there was a lot they didn't know about flying fuselage models. They competed with English model-builders at Halton Airdrome for the cup offered by Sir Charles Wakefield, and they failed to win a place!

On their return, Donald Burnham, national outdoor champion, set to work. He built a model, cracked it up, built another. He experimented in all kinds of weather, tried all kinds of wing-settings and adjustments and designs. At length he developed a big fuselage model that averaged 90 seconds in 35 different flights, made in sun and mist, wind and calm. A 70-second flight won the Wakefield Cup in 1929.

And here's the model for you to build. It's not so good-looking as some planes, but, after all, you are building the plane to fly. It is of sturdier construction than any other the League has described to you; and it's an unusually big fuselage model. Its wing is almost three feet in span; its fuselage length is more than two feet. Like the Chaffee C-4, it has no motor stick — the fuselage itself bears the strain of the rubber motor. It is of the low-wing monoplane type — the wing fits under the fuselage. It's exceptionally strong, yet it retains the



NO. 27. BURNHAM OUTDOOR



FUSELAGE MODEL

lightness that is typical of American model-building. Moreover, the model conforms to rules for the Wakefield competition and for the William B. Stout event for outdoor fuselage models — you'll find rules for this event in Chapter XXIV.

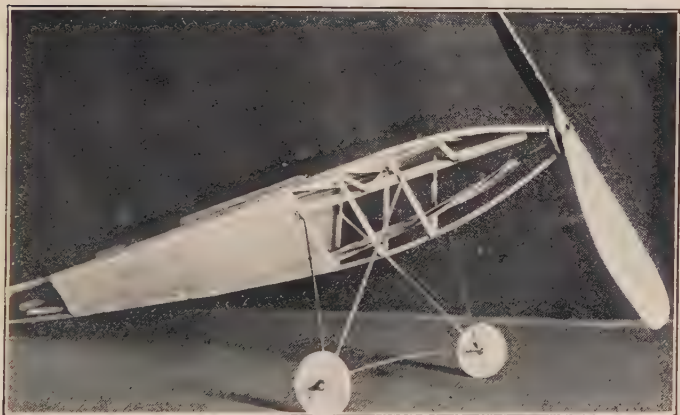
Start work by studying drawings and photographs in detail; read the chapter all through. Then, on large sheets of paper, draw out, full-size, accurate sketches of fuselage, wing, tail surfaces, landing-gear, and wheels. You'll need these sketches to check dimensions, and to guide you in your work. If you are building the plane from an A.M.L.A. kit, you will have all the drawings ready made.

Make your fuselage first. The longerons are cut from $1/8''$ balsa — you can sand them to the near-triangular shape shown in the diagram after the whole fuselage is cemented together. The two end cross-sections are $1''$ square, of balsa of the same size. Start the job by cementing the four front cross-section members to the four longerons, setting the longerons at slight angles to allow for their curve. When the cement is dry, set in the next set of cross-section members — their size is $1/8'' \times 1/8'' \times 1/2''$. Follow this procedure with all the succeeding members, allowing each set to become firm before adding another.

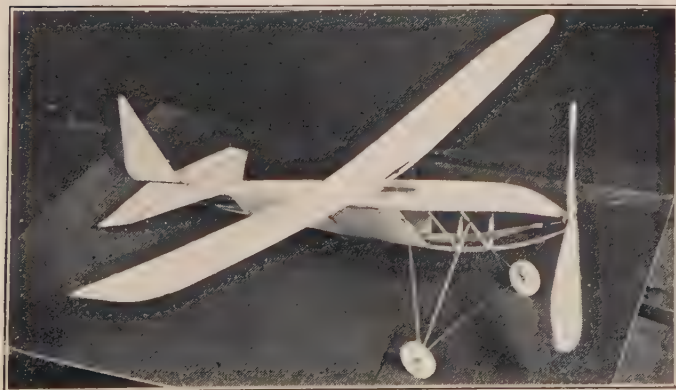
The next set will be $2''$ long; dimensions of the next four sets are given on the drawing. The succeeding five sets will be $2\ 1/16''$, $1\ 13/16''$, $1\ 1/2''$, $1\ 1/4''$, and $1\ 1/16''$ square; all are of $1/16''$ balsa. The last three sets have spacing of $2''$ and $1\ 1/2''$ separating them. Finally, set in the last cross-section, which is just like the first.



OUTDOOR FUSELAGE MODEL DESIGNED BY DONALD
BURNHAM, 1929 OUTDOOR CHAMPION



FRONT VIEW OF INDOOR FUSELAGE MODEL, SHOWING
METHOD OF MOUNTING MOTOR STICK



INDOOR FUSELAGE MODEL WITH FRONT SECTIONS LEFT
UNCOVERED TO SHOW INTERNAL CONSTRUCTION

Now, make the front and rear plugs, of $1/16''$ flat balsa. Each plug consists of two squares, one $1\ 1/4''$, the other $1''$, cemented together with the grain at right angles. Thus the smaller square fits snugly into the opening in the end of the fuselage. Make holes in the exact center of each; in the rear plug cement the rear hook as shown.

The thrust bearing, to be cemented to the front plug or nose piece, is a small strip of tin or other thin metal, bent as shown in the drawing marked 'Bearing.' In cementing it to the plug, be sure that the hole is exactly lined up with the hole in the plug.

Next, the tail surfaces. Note that the two stabilizer surfaces and the rudder are identical — make all three exactly alike. For each one make three $1/32''$ balsa ribs of the shape shown in the top view of the rudder, of the proper dimensions. Cut two center spars for each, making them of $1/32''$ balsa; cut front and rear spars for each also, of $1/16''$ balsa. Use your exact size sketch to get your dimensions exact. Cement the center spars into grooves cut in the ribs, and the front and rear spars in their places. Attach bent bamboo tips, bending the center spars to meet them.

Now, add the tail skid of bamboo, making it about $1\ 3/4''$ long, and cement in place the bamboo landing-gear struts. Note that each set of struts consists of two pieces, one bent to a sharp angle and cemented to the junctions of lower longerons and cross-sections 2 and 4, the other a straight piece cemented to the top of cross-section 3. You may do well to build the landing-gear a little longer than that shown in the diagram, to make sure that the revol-

ing propeller won't strike the ground as the ship takes off.

Cement the shock-absorber wire axles to the landing-gear as shown. Make the wheels of three discs each of $1/32''$ balsa, the center disc $2''$ in diameter, and the two outer discs $1\ 3/4''$ each. Set the grain in different directions. Burnham cut out sections of his center disc, for lightness. Cement the hub — a long slim bead like those used on dresses for decorations, or a tiny metal tube about $3/16''$ long — into the hole in the exact center; slip the wheels onto the axles, and bend up the axle ends to hold the wheels in place.

Now you may do the covering job. Apply the Japanese tissue very carefully, using a thin coat of cement on each fuselage member. It's a good idea to start the covering at the nose, cementing the paper at first only to the first cross-section, allowing it to dry and going on from cross-section to cross-section in this manner. Thus you can pull the paper very tight as you progress.

Cover the tail surfaces at the same time, then cement the surfaces in place on the fuselage. Scrape the paper from the fuselage members so that you'll be cementing wood to wood, not wood to paper. Note that the rudder is placed at an angle, to aid the plane in circling.

The wing comes next. First cut out your ribs. You had better make cardboard templates as models. The two center ribs are $5''$ long, the next pair $4\ 3/8''$, the next $3\ 7/8''$, the next $3\ 3/8''$, and the end ribs $3''$. Cut out the nine half-ribs at the same time; that for the center should be $1\ 5/8''$ long and the four pairs respectively $1\ 1/2''$,

1 3/8", 1 1/4", and 1 1/8". Cut four strips of balsa 2 1/2" $\times$ 1/16" $\times$ 1/16" for leading and trailing edges and center spars of the center section, and assemble this section, cementing the two 5" ribs, the 1 5/8" half-rib, and the four strips accurately in place. Then cut four long center spars 1/16" $\times$ 1/16" $\times$ 16 1/8", and four leading and trailing edges approximately 1/16" $\times$ 1/16" $\times$ 14 3/4". Now, assemble each half of the wing separately, adding curved bamboo tips at the ends.

Finally, cut the inside ends of the top center spars off enough so that, when they are cemented to the center section, the whole wing will have the dihedral angle shown — the tips should be 2" above the base at the center. Cement all three sections together. Cover the whole with Japanese tissue, and add the small superstructure shown in the upper right-hand corner of the diagram. This goes above the trailing edge of the center section, and serves to give the wing positive angle of incidence when the ship is put together.

The last job is the propeller, which is carved from a block 1 1/8" $\times$ 1 1/2" $\times$ 12". This gives a prop with a wide blade and a fairly high pitch. If you don't know just how to do the job, you may refer to the chapter on 'Propellers.'

It is necessary to 'dope' the paper-covered parts of an outdoor plane, to protect them from dampness. A good dope is a solution of five parts of banana oil to one of acetone for the entire plane, followed by a redoping of the fuselage with a solution of three parts acetone to one of banana oil.

Now, make a triple loop of your rubber motor, hook up the whole job (remember that the propeller shaft must go through the front plug and thrust bearing before it is glued to the prop). The wing is held to the fuselage by a rubber band; Burnham's model was so balanced that he set the leading edge of his wing about $1\frac{1}{2}$ " behind the fifth fuselage cross-section.

Here are some tips from Burnham on flying the model:

'For the first flight, it's well to give the six-strand motor about 650 turns. Stretch the rubber to $2\frac{1}{2}$ to 3 times its length as you start winding, and let it contract gradually. The motor will take as high as 850 turns, but a fellow will want to be mighty careful, for a snapping motor will smash his fuselage all to pieces.

'It's a good idea to use eight strands of rubber on particularly windy days. Rubber must be properly lubricated to get best results.

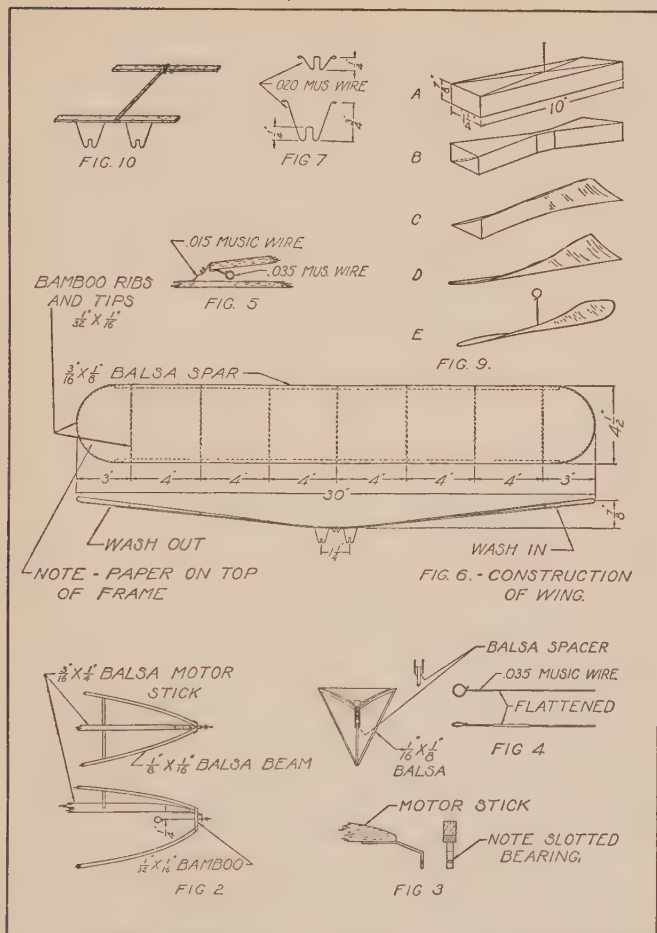
'If the plane is being launched r.o.g. from the grass, lift up the tail to free the tail skid.'

CHAPTER XVIII

THE INDOOR FUSELAGE MODEL

A FUSELAGE model has a built-up fuselage and is designed primarily to fly. Although not necessarily a copy of any real ship, it should have the general appearance of the large airplane. A scale model differs from the fuselage in that it is an exact replica of a large airplane scaled down, and seldom if ever flies. This is readily understood when we realize that the weight of the engine in an airplane brings the center of gravity well up in front, and to balance the airplane the wings have to be set also well up in front on the fuselage. This is all figured out by the designer before the plane is built, and whenever any of the parts of the plane are shifted, such as the engine or fuel tanks, a corresponding change must be made in the control surfaces. The scale-model-builder usually resorts to a dummy engine, which is much lighter than a real engine scaled down would be. Of course, this results in throwing the whole model out of balance, and either the wings must be moved back (which would take it out of the scale model class into that of the commercial) or enough weight added under the cowl to balance the ship. This makes it so heavy that flight is almost impossible, owing to the lack of lift at the slow speeds at which models fly.

The indoor fuselage model described here has several new features that make this model superior to the average



NO. 29. DETAIL DRAWINGS OF INDOOR COMMERCIAL MODEL

plane. Probably the most important of these is the method used to support the motor stick. This stick extends through the center of the fuselage and carries the strain of the rubber motor. It is shown very clearly in the drawings (Nos. 28 and 29) and photographs. Notice that it is supported in only three places, two in the front, and one in the rear. Sections A and C show the two front connections and Figure 5 shows the rear spring support. Whenever a rubber motor is wound ready for flying, there is a considerable force tending to twist the motor stick in the opposite direction from that at which the propeller turns. This force, known as torque, is sufficient in a light model to twist the whole fuselage enough to prevent flight. In order to prevent this, most model-builders design their fuselage structure sufficiently heavy to withstand the strain, thus adding a great deal of unnecessary weight. As most of the twist will be absorbed by two thirds of the stick, if free to turn, the motor stick in this model is supported at the rear end by the spring support as shown in Figure 5. The spring allows the stick to twist without affecting the fuselage, and anchors the end in place sufficiently to prevent the stick from moving back and forth or breaking loose.

The method used to attach the wing, although new in commercial planes, is familiar to flying-stick-model-builders. It allows the wing to be quickly adjusted and when not in use to be packed away in your airplane box. The three supporting beams must be exactly parallel or the wing clips will not fit over them at different positions. (See the small drawing showing these above the wing in the top view of the assembled drawings in Figure 1.)

Before beginning to construct the model, study the drawings carefully, making sure you understand exactly where each part belongs and how it is constructed. This will prevent you from spoiling part of your material as well as save you much time in constructing your model.

Let us begin by building the fuselage. This is triangular in shape, the strongest cross-section that could possibly be used, and is perfectly stream-lined the entire length. Figure 1 shows the construction of the fuselage with the full-sized cross-section drawings at one side. Cement together the ends of two $3/32'' \times 1/8'' \times 24''$ balsa beams in the shape to form the top of the fuselage. This will form the rear end of the fuselage. 6'' from this end glue a $1/16'' \times 1/8'' \times 1\ 1/4''$ crosspiece (section F). The section drawings show the distance across the fuselage including the thickness of the fuselage beams. Section F is $1\ 3/8''$ across, so that the crosspiece will equal $1\ 3/8''$ minus twice the thickness of the beam, or $3/16''$. Therefore, the crosspiece of section F equals $1\ 3/8''$ minus $3/16''$ or $1\ 3/16''$. Likewise section E, which is $2\ 1/4''$ across, has a crosspiece of $2\ 1/16''$. Six inches farther the $2\ 1/16''$ crosspiece is placed between them (section E), and $4\ 1/2''$ farther the $2\ 1/2''$ crosspiece is inserted. (See section D.) When the cement is thoroughly dry, the two spread projecting ends may be steamed by holding them over the spout of a tea kettle. They should be moved back and forth so that they will be steamed evenly from the last cross-brace to the ends. When these are thoroughly steamed, the ends may be bent together until they touch, thus forming the nose, and can be held in

place by thread binding. Now, by laying the whole upside down, flat on the table, and placing a heavy weight on top of it, the nose may be bent up and held in place with a $5/8''$ block under it in order to hold the curve until it dries.

While in this position the two other crosspieces, one $1\ 7/8''$ long and the other $2\ 15/32''$ long, should be set in their proper places. The $1\ 7/8''$ piece is $2\ 3/4''$ from the nose, and the $1\ 15/32''$ piece is four inches from the same point. These pieces should not be cemented in place until the beams are dry, but are placed in position to give them the proper curve while drying. As soon as they are thoroughly dry, all the joints should be cemented and the thread on the nose removed.

The crosspiece *G* is placed halfway between sections *D* and *E*, and is approximately $1\ 3/8''$ long. All the crosspieces should be cut to fit between the fuselage beams rather than the sizes given, which may vary on different models because of the amount of curvature. The crosspieces *H* and *I* are cemented between *E* and *F*, $2''$ apart, *H* being $2''$ from section *E* (see the drawing of top view, Figure 1). *H* is $1\ 3/4''$ and *I* is $1\ 1/2''$ long. This completes the top frame of the fuselage.

Now for the motor stick. This must be made from a piece of firm straight-grained balsa. When finished, it should be $3/16'' \times 1/4'' \times 20''$, well sand-papered and perfectly straight. The front end may be pointed slightly above the bearing as shown in Figure 3. The bearing is made from a small $1/16''$ nail, or part of a large cotter pin forged to the shape as shown. The hole for the propeller

shaft is .035 of an inch in diameter, and is slotted on one side by carefully filing. This slot must not be as wide as the hole or the propeller shaft will keep slipping out of place, preventing the propeller from turning. The purpose of this slot is to allow the propeller to be removed at will to change the rubber, which would be impossible with this type of fuselage using the ordinary bearing. The propeller shaft is flattened halfway between the hook and the propeller as shown (see Figure 4). The thin part permits it to slip into and out of the slot with ease when changing the motor. When finished, the bearing is cemented in place. Figure 5 clearly shows the construction of the rear hook which can now be cemented in place.

We can now assemble the motor stick to the top part of the fuselage. This is done by adding the four small braces that attach the motor stick to the side beams in sections A and C. These pieces should be beveled at the ends to make close joints and should hold the motor stick parallel to the upper side of the fuselage, three eighths of an inch from the bottom of the crosspieces. (See side view of assembly drawings, Figure 1; also the detailed drawing of nose, Figure 2. Notice that the bearing extends an eighth of an inch out beyond the fuselage.)

We are now ready to assemble the lower beam that forms the apex or bottom edge of the triangular fuselage. The front end of this should be well steamed for about seven inches from the end so that it may be bent upward. The bending may be done by drawing the outline on a sheet of paper mounted on a board. Small brads should be driven in on both sides of the drawing to hold the piece

in place while drying. Another way is to cement the rear end by means of the small $1/16'' \times 1/8'' \times 1/2''$ balsa upright to the top part of the fuselage and then to complete the triangular sections, D, E, and F, allowing them to dry thoroughly before steaming the front end. When these sections are finished and the cement set, the front end may be steamed and the piece bent and held in place by thread while drying. When this piece is dry, the sections B and C may be completed, and the two small $1/32'' \times 1/16'' \times 3/4''$ bamboo braces on the nose cemented in place (Figure 2). Notice the balsa wedges or spacers cemented in place under these pieces to keep them parallel and to allow enough room for the rubber motor to be taken out.

The small spring support should now be cemented in position. This is made from .015 music wire as shown in Figure 5.

We can now assemble the tail group. The elevators and horizontal stabilizer are made in one piece. Two bamboo crosspieces $1/32'' \times 1/16''$ are cemented across the top of the fuselage as shown in the drawing; one of these is nine and the other one eight inches in length. The 9'' one is set $3/4''$ from the end of the fuselage and the 8'' one $2\ 1/2''$ from the end.

While these are drying, we can bend the bamboo fin. The shape of this is clearly shown in the side view of the assembled drawings, Figure 1. Split — do not attempt to whittle — a piece of bamboo $1/16''$ square from your 15'' piece. When this is carefully trued up and sandpapered, it may be bent as shown. Bamboo, as you know,

is very pliable when hot, and can be bent to any desired shape by heating over a candle or alcohol lamp. Experienced model-builders will not have any difficulty here at all, and beginners can make an excellent job with very little practice. When the frame is bent to shape, it is split to form two fins, each $1/32''$ thick, the thin side parallel to the paper.

In attaching the fin to the tail groups, the base is cemented to the two crosspieces. Notice how the base extends $1/2''$ beyond the front edge of the frame of the fin in order to rest on the $8''$ crosspiece. The fin should form a right angle with the flat top of the fuselage. Sometimes it is set at a small angle to the thrust line or motor stick, to steer the ship in a smaller circle than it would normally fly in if left straight. As soon as the cement on the fin is dry, we can stretch our thread outline around the frame of the stabilizer as shown in the drawing. Every boy who makes kites has used a string to complete the outline around the frame for holding the paper. The thread outline is used in the same manner on this ship. Notice that the end of the thread is tied to the fuselage beams three inches in front of the eight-inch crosspiece and is stretched around the ends of both crosspieces and to the base of the fin one quarter of an inch beyond the end of the fuselage frame. After being twisted once around the base of the fin, the thread is stretched around the opposite ends of the crosspieces and back to the fuselage beam, to form the other side of the stabilizer. If you will carefully study the drawings of the top and side views of the ship, you will not have any trouble following the directions given above.

The landing-gear is the next part to construct. This is made from $1/32'' \times 1/16''$ bamboo. The method of attachment is clearly shown in Figure 1. The four braces are $5\ 3/4''$ in length, and may be split from one piece and the ends bent to fit the side braces of the fuselage. The other ends are joined at the axle which is made from a piece of bamboo $1/32'' \times 1/16'' \times 7\ 1/2''$. The wheels are cut from $1/8''$ flat balsa. A $1\ 1/2''$ circle should be drawn with a pair of compasses, and either with a sharp knife or razor blade the circle cut out to form the wheels. These wheels turn on small axle bearings formed from .020 music wire held in place by cementing to the underside of the axle. Small hubs are formed of balsa to prevent the wheels from coming off.

The wing used on this model is the flat or single surface type. A built-up wing may be substituted, but it is extremely doubtful if the added lift, gained by the double surface wing, will equal the added weight and drag due to this type of wing.

The three wing clips are clearly shown in Figure 7. The large or front ones are a half-inch longer than the single one in the rear. This gives the wing the necessary angle of incidence. Care must be taken to place these equal distances from the center and to see that the two front ones are exactly alike, or the model will not fly.

When the wing clips are set, the three pieces on the fuselage to which they clip may be set in place. The first two are $3/32'' \times 1/4'' \times 5\ 3/4''$ and the rear or center one is $3/32'' \times 1/4'' \times 6\ 3/4''$ long. Remember that these must be parallel and fit the clips tightly along their entire

length, or the wing will come off in flight. Should these become worn with use, a rubber band passed under the fuselage and over the wing and under the fuselage will help to hold the wing in place.

The fuselage may be covered next. The same method is used as was used in covering the wing. Care should be taken, in cutting the paper to fit the various parts, to make neat joints. The tail surface is covered on the bottom side only; the fin or rudder can be covered on either side. The section of the fuselage between *F* and the rear end is not covered, to allow one to get at the rear hook for winding.

The propeller is carved from a balsa block $7/8'' \times 1\ 1/4'' \times 10''$. Before you begin, study the five stages of propeller carving shown in the chapter on 'Propellers.'

A six-strand motor, consisting of a piece of $1/8''$ -32 rubber thread, ten feet long, with the ends tied together in a square knot forming a band, drives the propeller. This is folded to make six strands and one end dropped into the hole in the nose of fuselage and hooked to the rear end by means of the 'S' hook. The other end is looped through the propeller shaft, which is slipped into the bearing, and the ship is ready for flight.

CHAPTER XIX

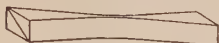
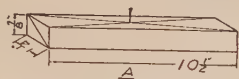
THE OUTDOOR TWIN PUSHER

Author's note: Since the new N.A.A. rulings require outdoor models to weigh one ounce for every fifty square inches of wing area, this model will have to weigh not less than three and one sixth ounces. Heavier parts are recommended for both the wing and frame members than called for in the drawings. Fuselage members of $1/8'' \times 3/8'' \times 40''$ will better stand the strain of the eight or ten strand motors required to fly the heavier ship.

THE twin pusher described below is identical with the one used by Jack Loughner in winning the 1926 Mulvihill Contest at Philadelphia and the Senior Outdoor Contest at Memphis in 1927. This was described in detail in the January, 1928, 'American Boy Magazine.' Thomas C. Hill, of North Carolina, built his 1928 championship model from these plans and won the A.M.L.A. trip to Europe. Lloyd Fish, of Washington, D.C., used the plans to build his plane that won him the 1928 playground championship. These are only a few of the victories credited to this champion model.

So far, the twin pusher holds its own for outdoor honors against all comers. Some model-builders have made changes in the design, the most successful being the addition of an auxiliary tail plane and a built-up elevator. Whether or not these changes improve the performance of the model is a question that only time can decide.

We will first describe the construction of the regular

OUTDOOR TWIN PUSHER.

B



C

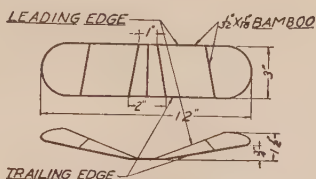


D



E

FIG. 6.



ELEVATOR FIG. 5.

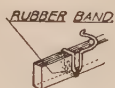
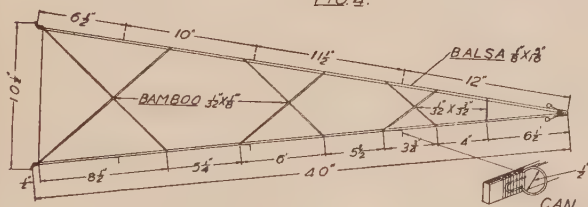


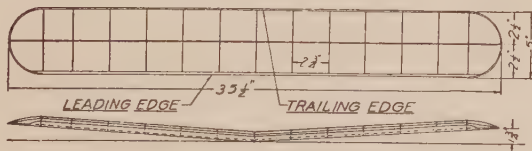
FIG. 4.



FIG. 3.



FRAME FIG. 2.

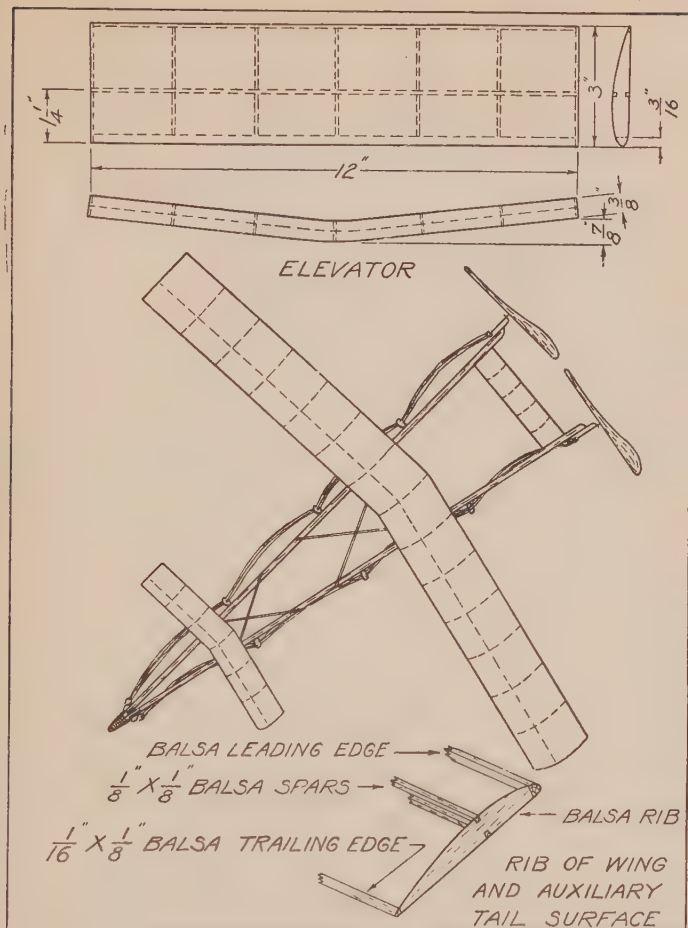


WING FIG. 1.

twin pusher, then tell how to add the built-up elevator and auxiliary tail plane. The wing has been described in the chapter on Construction Details. We will begin with the frame of the fuselage.

The A-shaped frame is made by fastening two balsa beams together to form a large 'V,' using cross-bracing to support and strengthen the whole. For a light model these pieces may be $1/8'' \times 1/4''$ and rounded well at the corners. A beginner should use beams $1/8'' \times 5/16''$ until he is familiar with launching his model, as the lighter frame will crack up very easily. The ends where the beams are joined should be cut at an angle to ensure a good joint and cemented in place.

The cross-bracing is the strongest bracing yet developed, and not only combines lightness with strength, but also stiffens the frame to withstand almost double the strain ordinary bracing would allow. The braces are made entirely of bamboo. Notice that the drawing shows heavier bamboo used in the widest part of the frame, as this is where the most strain is exerted. The first two Xs are made with $1/32'' \times 1/8''$ bamboo, the last two from $1/32'' \times 3/32''$ pieces of bamboo. These are inserted in slits formed in the frame and should be long enough to protrude through. These ends are cut off after the braces have all been adjusted and cemented in place. The slits can be formed by laying the beam flat on the bench and gradually working the point of your knife through. The center of the X should be bound with silk thread and cemented. These braces will straighten out the frame and hold it true, and in assembling you should take



NO. 31. DETAILS OF ANCILLARY SURFACES OF TWIN PUSHER

care to see that the frame is straight before the cement dries.

The bearings are made from one-sixteenth-inch nails or brads forged flat, and are drilled to allow the propeller shaft to pass through them. These are bent as shown in the drawing. The part lying along the beam (see Figure 3) should be flattened out considerably more than the rest to ensure a good fit on the beam. The bearings should not extend out from the frame more than one quarter of an inch. These are first cemented and then bound with silk thread.

The six cans or hooks along the side of the frames are very important, as they prevent the frame from bending under the strain of the rubber and breaking. The principle of these is the same as that employed on a flexible steel fishing rod, where guides or eyelets are used. These cans are made from Number 10 music wire, and their shape is clearly shown in the drawing.

You should leave the cans open at the top to allow the rubber to be slipped into place when it is wound. The correct positions for these are shown in the drawing.

The front hook is made of Number 15 music wire, and is bent around the front of the frame to form a yoke with two eyes on each side. These eyes or hooks do not need to be large, as 'S' hooks are used to fasten the rubber to them. The front hook should be bound with silk and then cemented.

In finishing the frame you can materially strengthen it by stretching a silk thread across the frame a half inch from each bearing where the bamboo braces enter the

frame. A coat of banana oil will add considerable strength to the frame.

In making the elevator, extreme care must be taken to get both halves identical. If one side has more incidence than the other, the plane will not fly properly. Notice that the trailing edge forms a flat 'V' and the leading edge forms a sharper 'V,' so that the outer edge of the leading edge is three quarters of an inch higher than that of the trailing edge.

The first step in making the elevator is to split the bamboo parts to size. You should form the tips out the same way as used in making the wing tips. The frame and ribs are all made from $1/32'' \times 1/8''$ flat bamboo. The halves of the trailing edge and the tips should be made from one piece of bamboo an eighth of an inch square, and then this is split to form two pieces for the two halves. Using this method the angle of incidence may be given the frame by bending this piece at the point where the trailing edge curves into the tip so that the tip will extend upward just high enough to fit the end of the leading edge. By bending and carefully fitting, a very neat job may be made. The leading edge is formed from one piece of bamboo bent in the center forming a 'V,' with the outer ends $1\ 1/2$ inches above the center. The 'V' formed by both the leading edge and trailing edges does not come to a sharp point in the center, but is bent flat as shown in the drawing. After the frame is bent and assembled, the five ribs are cemented in place as shown.

The last job to be done is the making of the propellers. There are two of these; one right-hand and one left-hand,

as they must turn in opposite directions to one another to keep an even flight. The balsa blocks for both propellers should be squared up on all sides and matched. When finished they should be $7/8'' \times 1\ 1/4'' \times 10\ 1/2''$. These dimensions may be altered to a slight extent without much change in the performance of the model. Remember that the diagonals on each end are opposite to each other and the propellers are right-hand and left-hand, turning in opposite directions. The propellers are carved in the same manner as described in Chapter V.

The small $1/4''$ washers are made from sheet brass or can be bought in department stores, where model airplane supplies are sold. These are used to cut down friction between the propeller and the bearing.

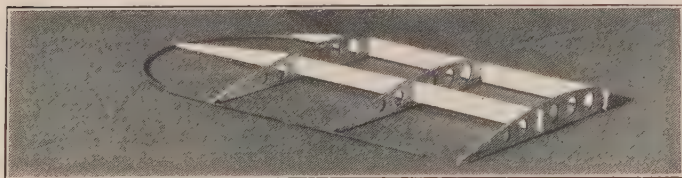
The plane derives its power from eight strands of $1/8''$ flat rubber. This rubber should have about two inches of slack when laid unwound in the cans. The pilot should always have a good reliable mechanic to work with him in winding the plane, and whenever possible the same one, as thus they will learn to work together better and prevent mishaps. When winding, 'S' hooks should be used to attach the rubber to the winder. With the mechanic holding the propellers at the hubs in such a manner as to stop them from turning, and also to take all the strain off the frame, the pilot backs away about four or five feet from the model, in order to stretch the rubber before winding, as more turns can be given when it is stretched. The winder should be turned so that the rubber is wound in the direction the propellers should turn in flight. Directions for making the winder will be found in Chapter VI.



HOWELL HELICOPTER



THE ASSEMBLED OUTDOOR TWIN PUSHER READY TO FLY



WING TIP CUT OFF TO SHOW METHOD OF ASSEMBLING
RIBS TO LEADING AND TRAILING EDGES

Notice that the bamboo tip is a continuation of the wing tip

The first flight should not be attempted until the plane has been adjusted to glide evenly, and then a trial flight made with only about five hundred turns on the rubber to test the adjustments. When the plane is properly adjusted it may be completely wound about twelve hundred turns and carefully launched.

In launching your plane, grasp the two propellers and gradually lift the nose into the air until it is tilted slightly upward. By releasing the plane with a slight push, you will be able to get off without mishap. Never launch your plane with the wind, but always against it.

When the addition of the built-up sections are decided upon, they may be constructed as follows. First the elevator is made. This is in reality a small built-up wing having a chord of about $2\frac{1}{2}$ " and a spar of 15". An airfoil similar to the one used on the wing or a thick, high lift section can be used. The construction is exactly the same as that of the built-up wing. Like the main wing, the elevator is given considerable dihedral angle. When one side of the finished plane is laid flat on the table, the tip of the other half should be not less than 2" above the table.

The auxiliary tail plane is made by building an airfoil section between the two fuselage sticks. The trailing edge of this surface should be located about $\frac{3}{4}$ " in front of the thrust bearings on the rear of the motor sticks. The two pieces of bamboo forming the rear X brace are removed or left out entirely. The spars of the section being used to give the necessary bracing. Ribs similar to those used in the built-up elevator are used to form the section.

One of these is cemented to the inside edge of each of the motor sticks and the others evenly spaced between these as needed.

The elevator may be held in place by the use of wing clips or a rubber band.

CHAPTER XX

VIRGIL RASSNER HYDROAIRPLANE

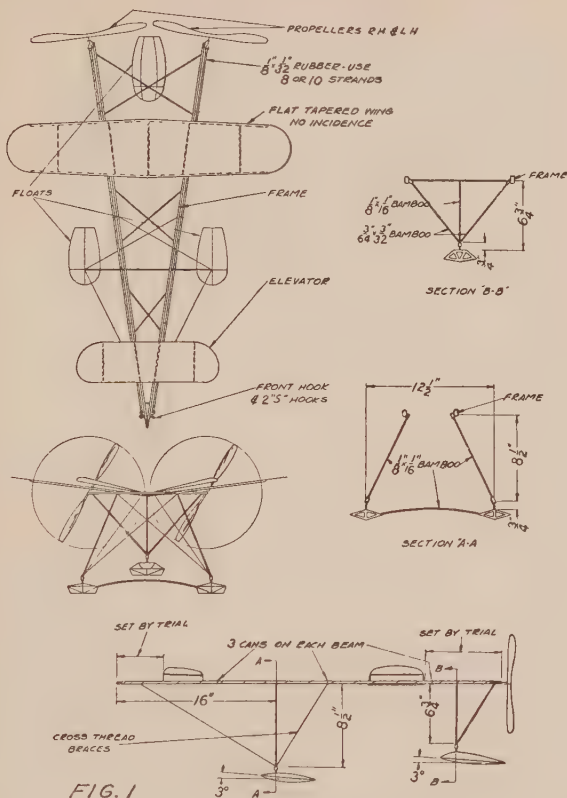
THE hydroairplane is a champion, having established the world's record of 2 minutes, 52 seconds for rubber-driven model hydros in 1921. It was designed and flown by Bertram Pond, one of the foremost model-builders in the country. Mr. Pond established the world's indoor record of 170 seconds, and held it for five years, till 1926, as well as having twice won third place in the Mulvihill Contest and sixth place once. Mr. Pond has given us the exact drawing of his record model with newly designed set of floats. Two of his students have won the National Playground meet with similar planes — Virgil Rassner in 1927 and Tudor Morris in 1928. Morris hung up a record of more than 12 minutes.

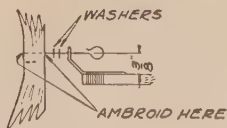
Before beginning to construct your model, study the drawings (Nos. 32 and 33) carefully. Note especially how the plane is assembled. This is shown in Figure 1, giving top, front, and side views of the assembled model. Compare these with the photographs of the model so that the position and shape of each part are fixed clearly in your mind. The two sectional drawings of the pontoons are shown to help you to see just how the floats are assembled. Section AA pictures just exactly how the cross-section of the front floats would look if they were cut through on the line marked *AA* and section BB shows the same view of the rear float along the line *BB*.

We will begin by constructing the frame (Figure 2). This is the A type, with cross-bracing similar to the one used on the twin pusher. The two beams are made extra heavy to take the strains that an R.O.W. ('rise off the water') plane is subject to. When finished the beams should be $3/16'' \times 15/32'' \times 38''$, rounded at the corners, well sandpapered and exactly straight. When these pieces are finished, they should be laid together, forming a 'V' with the rear ends $11\ 7/16''$ apart. While in this position the front ends should be beveled to make a neat joint and cemented. The yoke (front hook, Figure 8) can be fitted and cemented in place to hold the pieces while drying. A few turns of silk thread will make the joint much stronger. While the front end is setting, you can make the bamboo braces for the frame. Notice that the longer ones are made larger to prevent buckling when under the strain of the rubber. By the time you have these split to size, you can lay out the frame, beginning at the front brace, which is two and a half inches from the front. These braces extend through the frame, and when in place are cemented on both sides. The frame should be pierced with the point of your knife while laid flat on the bench. The end of the bamboo brace is sharpened to a point and then pressed through the slit formed by the knife point. When the braces are all in place, the frame should be carefully checked to see if it is exactly straight, and then the braces cemented in position.

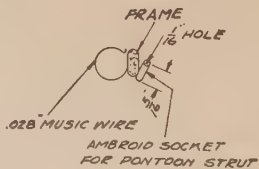
While the braces are drying, the metal fittings may be made. Begin with the six cans. These prevent the frame from bending when under the strain of the rubber in the

RASSNER HYDRO-MODEL

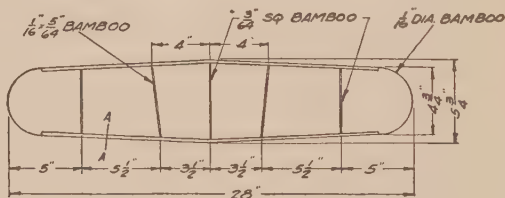




FORGED BEARING-FIG 10

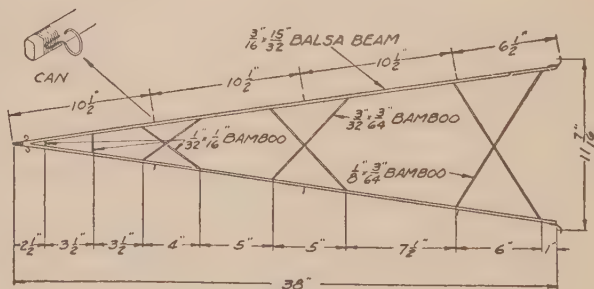


CAN-FIG. 9

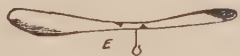
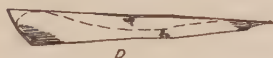
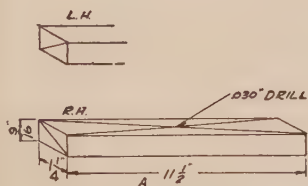
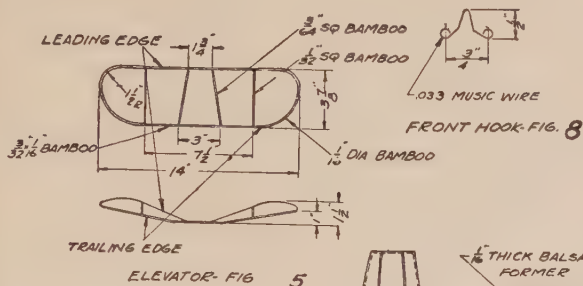


SECTION "A-A"

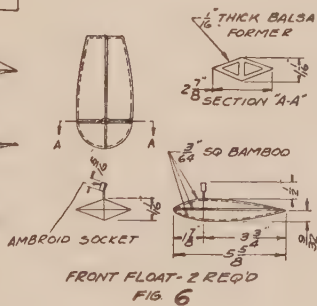
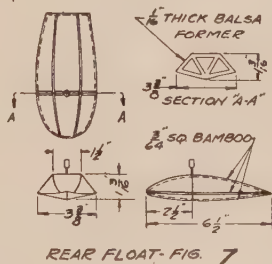
WING-FIG. 3



FRAME FIG. 2



PROPELLERS- FIG. 4



same manner as eyelets on a fishing rod prevent it from bending. The shape of these is clearly shown by Figure 2 in the small drawing in the upper left-hand corner and the end view in Figure 9. There are three of these on both beams made from .028" music wire; the spacing for them is given at the top of the drawing. The loops should be a half inch in diameter so that the rubber will have plenty of room in which to turn. Notice how the wire is bent at right angles to the loop in order to fit parallel to the beam, where it is cemented and bound with a few turns of silk thread in place.

Figure 10 shows the forged bearings, which are made from a small nail drilled with a .035" drill to fit the propeller shafts. When in place on the shaft, this hole should be just three eighths of an inch from the beam (see drawing, Figure 10). Thrust bearings already drilled and bent are furnished in the kit.

We are now ready to construct the wing. This is a single surface flat wing, in many ways resembling those you made for your indoor models. The four spars are made from balsa strips, finished to the shape as shown in section AA and are 11 5/8" long. The position of the five ribs should be next marked off on them and we are ready to begin assembling.

If you make a large drawing the size of the wing, it will help you to get the correct angle to your spars as well as give you a form to which to bend your wing tips. Two spars, end to end with the curved side down, form the leading and trailing edges. The ends of these spars are one inch closer together than they are at the center.



SIDE VIEW OF RASSNER HYDROAIRPLANE



RASSNER HYDROAIRPLANE, LOOKING FROM THE TOP AND
FRONT

The dihedral angle may be given by placing a block under the wing so that their outer ends are $1\ 11/16''$ high while the cemented butt joints are drying at the center. The wing tips should be bent from one piece of bamboo $1/16'' \times 1/8'' \times 9''$ to fit the form of your drawing. When you have them bent correctly, they should be split and the corners well rounded and cut to length. Be sure you leave enough on the ends of the tips to allow a half inch for lapping when joined to the spars.

The spars can now be grooved so that the tips will set flush with the outside of the spar to form a continuous curve. When this is done, cement the tips in place, being careful to keep them parallel to the spars so that when the paper is put on it will lie flat along the entire length of the wing. Next the grooves for the ribs should be cut $1/16''$ deep, and the ribs cemented in place just even with the surface of the spars. The wing is covered with Japanese imperial tissue; beginning with the center rib, the frame should be painted with banana oil and the paper laid in place. Wrinkles can be prevented if the paper is perfectly flat when placed in position. Should your paper contain wrinkles, it must be ironed out and allowed to cool to the room temperature before using, to prevent future warping. As soon as the paper dries, another section may be covered, always working from the center toward the tips until the wing is covered. The edges of the paper can be trimmed with a sharp razor blade or by carefully rubbing with fine sandpaper. The rough edges can be fastened down by painting with banana oil. The entire surface of the wing is later painted

or doped with a solution of five parts of acetone to one of banana oil. This is followed when dry by four separate coats of banana oil. This is to shrink and waterproof the wing. Most hydros get wet all over at one time or another, and must be made waterproof to prevent them from being spoiled.

The next job is the carving of your propellers. There are two of these, one right-hand and one left-hand, as they turn in opposite directions to one another and thus neutralize the torque. These are carved from blocks, $9/16'' \times 1\ 1/4'' \times 1\ 1/2''$. Like the rest of the plane, the propellers must be given five coats of banana oil to waterproof them.

Figure 5 shows two views of the elevator. This should be carefully studied before construction is started. The entire frame is made of bamboo bent to the shape as shown in the drawing. This is constructed essentially the same as the one used on the outdoor pusher.

The success of the entire plane as a hydro depends on the floats. These must not only be properly constructed, but must be assembled correctly or the plane will not rise from the water. In designing pontoons we have to make them large enough so that when they are totally immersed the weight of the water displaced will be three times the weight of the whole plane. This allows the floats to sit well up on the water when supporting the plane. Notice that Figure 1 shows the floats set at an angle of three degrees. This may vary from two to five degrees without much change in efficiency in the floats. The 'V' bottom floats are much better than the flat type

so common on models, as they prevent the plane from turning on its course when taking off. This type also rises from the water much more rapidly, as it cuts down suction on the bottom of the float, and in landing they take up the shock of landing, as the 'V' cuts into the water and breaks the force of the blow.

The floats are formed of $3/64''$ bamboo bent around the balsa former shown in the drawings. This former is cut from $1/16''$ flat balsa to the shapes as shown in Figures 6 and 7. Notice the triangular lightening holes to cut down weight. The corners of these formers should be painted with cement to strengthen and prevent chipping.

The two front floats (Figure 6) should be made first. If you will make a full-sized drawing of the top view, it will help you to bend to the correct shape the V-shaped bamboo pieces which form the sides. These pieces can all be made from $3/64'' \times 1/8'' \times 15''$ bamboo, and the parts for both pontoons split from one piece. When the side pieces are completed, they can be cemented to the balsa former as shown in the drawing. The top and bottom pieces can now be bent and fitted in place, completing the frame of the float. When finished, the nose should be rather flat at the extreme point rather than sharp, to prevent it from nosing under in rough water. Before covering, the bamboo strut which supports the cement socket must be cemented into place at the exact center of the pontoon and the balsa former. The floats are covered with tissue given five coats of banana oil to waterproof them. Care must be taken not to puncture the floats in covering and to check them to see that there

are no leaks. The rear float is made exactly in the same manner as the front floats and differs only in size and by the addition of two ribs on top instead of one.

If the model could not be taken apart when not in use, it would be very unhandy to carry about. For this reason it is equipped with small sockets which allow the supporting struts to be slipped on or off at will. These sockets are formed by rolling tissue about a $1/16''$ nail, winding the tube thus formed with a few turns of thread to increase the strength, covering the whole with several coats of cement. When these are dry, they can be slipped off the nail and cemented to the pontoons as shown in the drawing. Similar sockets are cemented to the beams and to the cross-bracing where the supporting struts fasten to the frame.

Study the assembly drawing of the plane and the shape of the struts; if you cement the sockets to the frame at an angle as shown in Figure 9, the struts will have to be bent only at the point where they enter the pontoons. These struts are made of $1/16'' \times 1/8''$ bamboo and are rounded at both ends to fit into the sockets. The front pontoons have two of these running to each side of the frame. The floats are held apart and the whole strengthened by a curved brace joining the two. This brace is cemented to the edges in line with the balsa formers.

Additional bracing is given to the floats and undercarriage by two threads running from the sockets to the second cross-brace on the frame, six inches from the nose. Two other threads cross each other to the opposite side of the frame.

The rear float is supported by three struts. The center

one fits into the socket at the center of the last cross-brace at the rear end of the frame. The two supporting braces extend from this center strut, just above the socket, where they are joined by cementing, to one inch from the ends of the beams, where the ends of the last cross-braces enter the frames. They fit the sockets cemented here to receive them. By using this method of attachment, the entire undercarriage and pontoons may be quickly put together or taken apart for packing in an airplane box.

The motive power for this ship is derived from two ten-strand 1/8"-30 rubber motors. The wings and elevator are held in place by rubber bands which extend under the frame and over the surfaces, thus allowing them to be shifted to get the right setting.

The ship should be glided before attempting to fly it. As the pontoons are easily punctured, this should be done in soft grass or under similar circumstances where the floats will receive protection. If the plane attempts to climb or nose up in the glide, the wing should be set back; if it dives, it should be set forward.

In launching, the plane should be wound with a double winder, giving it about six hundred turns to begin with, using 'S' hooks to connect the motor to the yoke when transferring it from the winder. When wound, the plane is set on the water and held by the propellers. When all is ready, these should be released at the same instant, and if the plane is properly constructed and adjusted it will skim lightly over the water for a short distance; then, gathering speed, it will slowly rise from the water and the chase is on. The seaplane, like all other ships, should be launched against the wind and never with it.

CHAPTER XXI

HOWELL HELICOPTER

THE helicopter shown in the photograph opposite page 198 is one of the many types that model-builders are experimenting with all over the country. This particular model with a record of over sixty seconds, was designed by David Howell, of Detroit.

The model is designed for hand launching, although it can be made to R.O.G. by constructing three supports cemented to the sides of the tubular motor stick. These should be evenly spaced and set so that they support the machine similar to the supports used on Christmas trees. $1/16''$ square balsa, three inches long, will serve the purpose.

The machine consists of an $8''$ R.H. propeller mounted on a tubular motor stick. Four vanes mounted on balsa strips are cemented to the motor stick $7/8''$ from the upper or propeller end. The propeller is driven by two strands $1/8-30$ flat thread rubber. The torque of the propeller causes the vanes to revolve in the opposite direction to the propeller, securing additional lift.

Let us begin by making the motor stick. This is a $3/8''$ diameter balsa tube with $1/32''$ thick walls. The upper end has a thrust bearing similar to the ones used on indoor planes. This is cemented to the outside of the tube with the curve bent over the end of the tube. The size

of the bearing should be such that the hole for the propeller will line up exactly with the center of the tube.

The lower end of the tube has a hairpin-shaped rear hook. This is bent so that it forms a $1/16''$ round eyelet at the center of the 'U.' The 'S' hook fits into this eyelet and keeps the rubber exactly centered. All wire fittings are made from .020 music wire.

The propeller is the conventional type carved from a block $3/4'' \times 1'' \times 8''$. The rubber motor cannot have any slack or it will knot up in the tube and prevent it from freely unwinding.

The four vanes are made very similar to the cambered wings used on indoor models. They are rectangular in shape, with a chord of $2\ 1/8''$ and a span of $4''$. They have three slightly cambered ribs, one at each end and one in the center. The entire frames of the vanes are made of $1/32''$ square balsa. When finished, they are covered on the upper surface with Japanese tissue.

The vanes are mounted on four $1/16''$ square balsa spars $6\ 1/4''$ long. These have a slight bend upward $2\ 3/4''$ from the outer end. When laid flat on the table, the end should be exactly $3/4''$ high. A $1/16''$ thick balsa disc or washer, with an outside diameter of $1\ 1/8''$ and a hole of $3/8''$ diameter, is cemented to the motor stick $7/8''$ from the upper end. This disc helps to support the spars. The spars are cemented to the inner and center ribs of the vane $7/8''$ from the leading edge. The vanes are set at an angle of incidence. That is, the leading end is $3/8''$ higher than the trailing edge. The upward bend of the spars gives the machine dihedral angle.

Remember that in order to fly properly, each vane must be exactly the same size, set at the same angle (both dihedral and incidence), and equally spaced. Any variation will cause the plane to roll from side to side while in flight.

Howell increased his endurance in low-ceiling rooms by sticking a needle in the center of his propeller. This permits the machine to continue to revolve, without the propeller striking the ceiling.

CHAPTER XXII

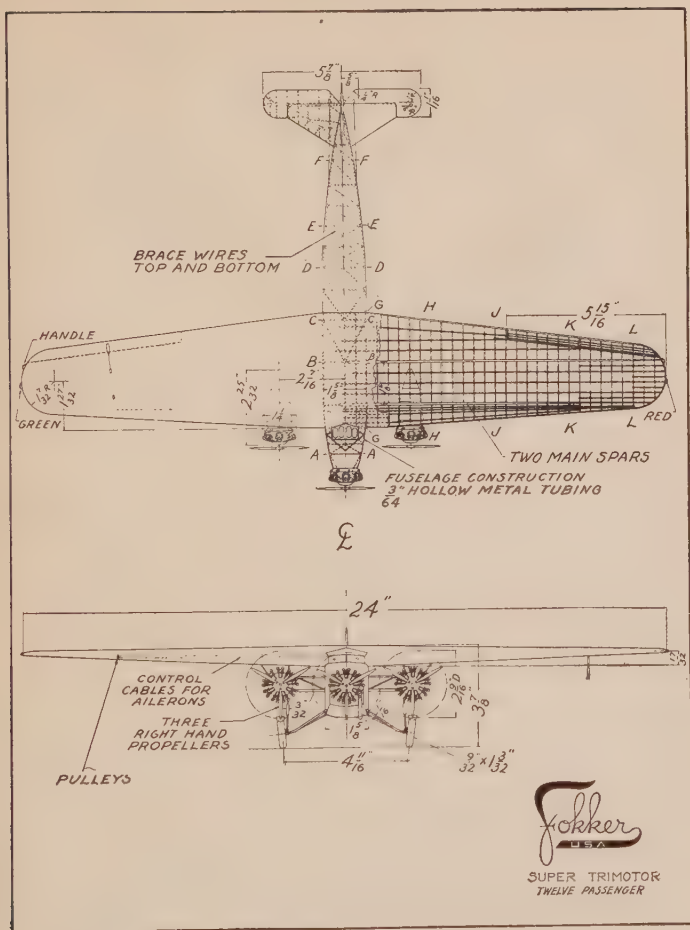
TRUE SCALE MODELS

THERE is a world of difference between building airplane models that fly and scale models. The flying-stick models that have been described are designed to give you the longest possible flight and they do not greatly resemble large ships. When you build a scale model, you pay no attention to flying quality, but attempt to duplicate, as exactly as possible, some large ship.

Genuine scale models seldom fly. The wings, for one thing, are too far forward. On a large ship, the wings must be well forward, to balance the weight of the engine. But there is no engine on a scale model. Of course, on your model, you could set the wing farther back in order to balance the ship — but when you do that, you no longer have a scale model. The scale model, remember, is built to duplicate, exactly, a large ship.

Constructing the scale models described in this article will be a new and extremely worth-while experience. It will teach you the essentials of big ship design.

The Airplane Model League of America prepares each year three large scale-size drawings of the outstanding airplanes. These drawings show as many details as it is possible to show without making them too complicated. In addition to the detail drawings, photographs of the entire plane and close-ups of the more difficult parts are given. These drawings may be obtained from the League at twenty cents each.



PASSENGER SUPER-TRIMOTOR

No attempt is made to tell the contestant how to build his model or what material to use. Since the object of the contest is to teach airplane design, the contestants are urged to use as much originality as possible. Additional information should be obtained about the construction of the plane, materials used, number of accessories and location, color and decorations, engine, cowlings, and any other details that are not given on the drawings, but which will help more fully to duplicate the large plane. This information can be obtained from back numbers of the aeronautical magazines, from the manufacturer of the plane, or possibly from one of the planes at your local airport. Digging up this information is part of the contest, as credit is given for all additional details in judging the models.

Some fellows are satisfied with models made with solid fuselage and wings. Others will duplicate the large ship even to the metal framework. Some of the models entered in the 1929 Contest had built-up fuselages, controls operated from the cockpit, wings with every rib duplicated, imitation instrument panels, and in the Ford trimotor models even the metal covering was corrugated. Engines were made by carving cylinders out of wood, which were used as patterns. Plaster-of-Paris moulds were made from these and lead castings poured. Exact propellers were filed from solid metal blanks.

One should plan to spend not less than three months on his model if he expects it to place up in front in any first-class contest. Before starting your model, read over carefully the instructions for conducting a scale-model



contest. This will give you some idea just how the judges will check your models. The scale-model drawings shown are taken from the large drawings available from the League. Study these carefully before deciding on which one you will make. Then go out after additional information to make sure that you will be able to find out everything necessary for the completion of the model.

CHAPTER XXIII

MODEL AIRPLANE CLUB ORGANIZATION

WHENEVER possible, boys interested in building and flying model airplanes should organize a club. Boys who build models in groups will progress much faster than boys working alone. They have the advantage of comparing planes and profiting by each other's experiences. Clubs enable the boys to interest other boys as well as adults, provide groups for contests, encourage research work, and give the boys confidence and experience in flying in competition.

The first step in organization is to assemble all the boys who are interested and elect officers. The suggested constitution given at the end of this chapter may be used as it is or modified to suit the individual needs of your club. The membership should be restricted to fifty members, as a larger group than this becomes unwieldy. Only boys who are definitely planning on constructing models should be admitted, as others will harm rather than help the group. Definite procedure for dropping dead timber should be adopted and the rules strictly enforced.

Obtain, if possible, a definite meeting place. If a club-room is available, it can be made more attractive by obtaining literature on airplanes, such as books and aviation magazines. A scrapbook should be kept with notes of all the activities of the club, such as newspaper clippings and results of contests. Airplane pictures and, when possible, airplane propellers hung on the wall give a

clubroom an attractive appearance. If a separate room for your club cannot be obtained, get permission to meet in your manual training room, after school, at the Y.M.C.A., or in your local church. Almost any organization interested in boys' work will be glad to let you meet in their building as long as the club attends to business and does not misuse the privilege.

Every club should have an adult as sponsor, one who will not only attend your meetings, but will also build planes. Your manual training teacher would be an excellent person to have, as he can help the boys in many ways as well as make valuable suggestions. Scout masters, preachers, and in fact any adult interested in airplanes and boys will do as sponsors.

As soon as your club is organized, affiliate with the Airplane Model League of America, the National Model Organization, and see that each member fills out an application and obtains his membership card and button. Application blanks and club information may be obtained, upon request, from the A.M.L.A. headquarters at 550 Lafayette Boulevard, Detroit, Michigan. A list of all the members, with the information about each and requests for the application blanks, should also be sent in by the secretary of each club, to be filed at the national headquarters.

The A.M.L.A. stands ready to help you organize your club, furnish kits and materials at cost, answer all the questions that you have on aviation, promote contests between clubs, establish categories for contests, and in every way possible aid model-builders.

This organization has the approval of the National Aeronautic Association. It not only has the support of the leaders in aviation, but numbers many of them among its officers. In less than a year the organization has grown from a small group of thirty members to over one hundred and fifty thousand.

Once your club is thoroughly on its feet, you should not have any trouble getting support. You will find, as soon as you have some planes that can be depended on to give real flights at demonstrations, that civic clubs and other organizations will want you to fly for them at their entertainments. Do not attempt to give exhibition flights until you have at least five or six models that will fly not less than thirty or forty seconds. When you are ready, go to the local newspaper, the Rotarians, to the Kiwanis, to Lions, to one or more of the lodges, to the Chamber of Commerce, or some similar organization. Tell them what your club is doing; that your model airplanes will really fly. Prove it to them in their offices. Ten to one they will be interested and invite you to give an exhibition (if not, try another) at their next meeting. After that it is up to you. If you do well, the chances are they will help you to get financial support and possibly to send your local champions to the national contests.

See that your club meetings are interesting. Perhaps you will want to appoint a programme committee to take care of that. Invite men who are interested in aeronautics to talk to you. Lay out a definite programme of experiments, such as rubber tests or propeller research and see that it is carried through. Set aside part of the

meeting time for flying and try to instill a spirit of competition at these sessions. Keep a set of club records and award some sort of recognition to the holders of these records.

Possibly you will want to organize the members of your club into groups: some known as ground men, flying cadets, pilots, aces, and assistant instructors. Clubs have worked out excellent plans whereby they can encourage the members to study aviation and to proceed with their model work. Usually in these clubs the new member has to enter as a ground man. In order to pass from one group to the other, he must pass an examination on some phase of aviation as well as to construct certain models with set specifications or requirements. These tests and examinations should be progressive in nature; that is, a beginner would not be expected to build as good an airplane as the advanced student or to know as much about aviation. Many clubs start with the Baby R.O.G. and require that each boy earn his honor certificate from the League before he can become a flying cadet. Then he must construct the indoor pusher and get his certificate before he can become a pilot, etc. Material for the examinations can be obtained from this book, and this gives the student a chance to get all the required information, drawings, etc., from one source.

Exhibitions and contests can be livened up by mixing in stunts. A few suggested ones are given; you will think of a lot more; and you will find that often these stunts furnish more amusement than the main contest.

Balloon 'strafing' always gets a hand from the audience

and creates a spirit of competition among the fellows. A number of rubber balloons are suspended from the ceiling by strings. The contestants equip their planes with pin points. These can be pushed through the center of the propeller hub or ambroided to the leading edge of the wing, near the tips. At a given signal the contestants launch their planes toward the balloons attempting to break them by piercing with the pin point. The plane that explodes the most balloons wins the prize. The Baby R.O.G. should be used for this contest, as it makes a faster flight and helps to increase the interest.

Bombs and parachutes can be dropped by many ingenious methods. Some of the boys build small balsa bombs with fins, like the real ones, and, by means of a hook under the fuselage, they are dropped from a great height. The hook is bent so that it will hold the bomb as long as the plane is climbing, but as soon as it levels out the bomb slips off. Small firecrackers can be dropped so that they will explode in the air before landing. This is done by tying the fuse to the fuselage with thread as close to the firecracker as possible. Just before launching the plane, the fuse is lighted and the plane released. When the fuse burns up to the thread, the thread is burnt and the cracker drops. This stunt should never be tried over the heads of an audience, as it would be apt to cause confusion and possibly a panic. When using pins, caution the audience so that they will watch that no one's eyes are put out when the planes land.

The high-climb contest is always interesting, when the room in which the flying takes place has a high ceiling.

Six or seven contestants are lined up and a judge assigned to each. The object is to see whose plane hits the ceiling first. Where it is practicable, the planes can be made to take off under their own power.

Looping-the-loop is another good stunt. The loops should not be counted unless it is a perfect loop. The plane making the most loops in one flight wins. The record so far for models is ten in one flight with eleven additional loops that were not perfect and so could not be counted.

In all stunts and contests the planes should have certain restrictions to regulate their size and to even up the contest. A Baby R.O.G. with an eight-inch fuselage would not have a chance in stunting or endurance against a plane with a ten-inch stick. In Chapter XXIV are given the rules used at all national contests for duration planes. They have been found to be very workable, and you can base your rules on these using the same restrictions.

A SUGGESTED AIRPLANE MODEL CLUB CONSTITUTION

ARTICLE I — NAME

This club shall be known as the Chapter of the Airplane Model League of America.

ARTICLE II — OBJECT

The object of this club shall be to promote model aviation.

ARTICLE III — MEMBERSHIP

Any person over years of age may become a member of this club upon receiving a majority vote of the members present at any regular meeting.

ARTICLE IV — OFFICERS

The officers of this club shall be: President, Vice-President, Secretary, Treasurer, Sergeant-at-Arms, and Advisor. They shall be elected every six months by a majority vote of the members present. (The advisor should be an interested adult, skilled in promoting activities.)

ARTICLE V — DUTIES OF OFFICERS

SECTION 1. The president shall preside at all meetings of the club.

SECTION 2. The vice-president shall preside in the absence of or at the request of the president.

SECTION 3. The secretary shall keep the minutes of the proceedings of the club and conduct the correspondence.

SECTION 4. The treasurer shall keep a record of all money received, spent and on hand, and pay only such sums as shall be authorized by the club, and upon order signed by the president and secretary. He shall make a report in writing at each meeting of all money received, spent, and on hand.

SECTION 5. It shall be the duty of the sergeant-at-arms to assist in keeping order.

SECTION 6. It shall be the duty of the advisor to assist the club in its programme of activities.

ARTICLE VI — COMMITTEES

SECTION 1. There shall be a Programme Committee which will, with the approval of the president, arrange for interesting programmes.

SECTION 2. There shall be a Research Committee for investigating and experimenting on new material and new design and reporting its findings to the club.

ARTICLE VII — MEETINGS

SECTION 1. The club shall hold a meeting every

SECTION 2. Special meetings may be called by the president at the written request of five members.

BEGINNING TO FLY

ARTICLE VIII — DUES

The dues of this club shall be cents each regular meeting. (The club collects money for its own purposes only; it pays no dues to the A.M.L.A.)

ARTICLE IX — ORDER OF MEETING

The order of exercises shall be as follows:

- | | |
|-----------------------|--------------------------|
| 1. Call to order | 5. Reports of Committees |
| 2. Roll Call | 6. Unfinished Business |
| 3. Reading of Minutes | 7. New Business |
| 4. Treasurer's Report | 8. Adjournment |

ARTICLE X — PARLIAMENTARY LAW

'Cushing's Manual' shall be the parliamentary authority of the club.

ARTICLE XI — AMENDMENTS

This constitution may be altered or amended by a two-thirds vote of the members present.

CHAPTER XXIV

RULES AND SUGGESTIONS FOR CONDUCTING AN AIRPLANE MODEL CONTEST

IN ACCORDANCE WITH THE RULES ADOPTED BY THE
NATIONAL AERONAUTIC ASSOCIATION AND FÉDÉ-
RATION AÉRONAUTIQUE INTERNATIONALE

THE model airplane flying contest has a technique all its own. It's not a new technique — such contests have been held for many years, but only in the past year has the building and flying of model planes become widespread. This progress has been due, chiefly, to national sponsorship of model aviation by 'The American Boy Magazine' and by newspapers coöperating with it. During the coming years, there will be a tremendous increase in the number of local flying meets. To help the groups holding these meets — to give them in brief form the experience of men who have helped conduct contests during the past five years — the author has added the following suggestions and rules.

Types of Contests:

Three kinds of contests are generally held: indoor flying, outdoor flying, and scale model. For the indoor and outdoor contests, rules have been laid down by the National Aeronautic Association. The scale-model contest may be conducted under rules prepared by the Air-

plane Model League of America. Copies of the rules for all three contests may be obtained from A.M.L.A. Headquarters, American Boy Building, Second Boulevard at Lafayette, Detroit.

Selection of Fields and Halls:

Your first job in preparing for the contest is to select a field for the outdoor meet, and halls for the indoor and scale-model meets. *Be sure to pick the right kind of places.* Here's what you want:

For the outdoor meet, a field at least one half mile square. To understand why such a large field is needed, you must understand how the outdoor plane performs. Twin pusher planes, launched from the hands, rise slowly in the air, describing wide circles. They often attain an altitude of several hundred feet, and as they circle they drift with the wind. Flights of four minutes are common and flights of over ten minutes are not unknown. In that time a plane can drift a long distance. In a meet held in Central Park, New York, one ship disappeared over the roof of a tall building, never to be recovered, and another landed in an open car on a near-by boulevard. Boys value their outdoor planes at more than fifteen dollars, and they are extremely reluctant to risk them in a too-small field bordered with buildings and busy streets. Parks, unless they are extremely large, are usually unsatisfactory. Athletic fields are much too small. An airport is ideal. On calm days a large park should do.

For the indoor meet, a large non-drafty hall. The indoor plane is affected by strong air currents. Its flight

might be disturbed so that it will lose altitude, or it might be blown over against a wall where it will attack vainly several times and then swoop for the floor. The ideal hall in your city is the largest non-drafty hall with the highest ceiling. Preferably there should be no posts, girders, or other obstructions. The duration of an indoor plane will depend largely upon the altitude it can reach. A high-ceilinged hall makes possible good flying records.

One national contest has been held in a school auditorium, but even here the flight of two planes terminated in huge indirect lighting bowls. The site of the 1928 National Indoor Contest, the Olympia Stadium at Detroit, is ideal. It has a 90-foot ceiling. It is extremely spacious. Drafts can be eliminated. If this ideal isn't available, an armory, a large auditorium, or theater should prove a satisfactory substitute.

For the scale-model contest you need a well-lighted hall with plenty of floor space so that the models can be displayed on tables. The ceiling need not be high, nor is draft a factor, since scale models do not fly, but are judged only on appearance, fidelity to scale, and similarity to man-carrying planes.

PRELIMINARY WORK

Selection of Prizes:

Prizes should be ordered well in advance of the contest. While the type of prize and the cost depend entirely upon the magnitude of the contest, this general rule is useful: Offer prizes for a great number of places so that many

entrants will share in the rewards. Give a certificate of merit to every one who enters. Equip yourself, in advance, with plenty of A.M.L.A. honor certificate applications, so that every boy or girl who makes an exceptional flight may apply for one.

Prizes for contests held in the name of the Airplane Model League of America may appropriately bear the official wing design and the letters 'A.M.L.A.,' provided permission has been obtained from 'The American Boy Magazine.'

Publicity:

In addition to newspaper stories concerning the contest, on the contenders, on the preparation of planes for competition, on the rules, etc., you will find the following publicity useful:

1. Announcements in schools.
2. The organization of a 'flying squadron' composed of several expert model-builders. Book this squadron for demonstrations before luncheon clubs, at banquets, in schools and elsewhere. These stunts invariably 'steal the show.'

Interest the aviation leaders of your city, the chamber of commerce, and other organizations in coöperating with you.

Entry Forms and Other Supplies:

You will want to provide the following supplies well in advance of the contest date:

1. Contestants' badges or tags. These badges will be

worn by the entrants and will pass them into the hall or field at all times.

2. Contestants' cards. A suggested form follows:

(Your City) MODEL AIRPLANE FLYING MEET

(Date)

Name.....

Age..... Address.....

Representing.....is eligible
(School or Club)

to compete in the.....Model
Airplane Flying Meet. He is entered in the

Indoor.....

Outdoor.....

Scale Model.....

Each contestant will carry this card with him at all times. It will indicate that he has paid any fee that may be charged and that he has complied with the necessary conditions to entering.

3. Scale-model score cards.

4. Entry blanks. One entry blank will do for both indoor and outdoor contests. Here is a suggested form:

THE (Your organization) AIRPLANE MODEL FLYING MEET
.....(Your City).....(Date)

Director of the Airplane Model Meet
Address

I wish to enter the Airplane Model Meet to be conducted by (your organization) on (date). I understand that each model plane I enter must be built by myself; that each must be driven by rubber strand motor; that for the indoor contest, planes must have a distance between propeller bearing and rear hook not to exceed 15 inches,

and for the outdoor contest, a wing loading of 1 ounce for every 50 square inches of wing area.

Indoor..... Outdoor.....
(Put a cross after each division you intend to enter)

My name is.....
(Write or print full name clearly)

My address.....
(Street) (City) (State)

Date of birth.....

I represent the.....
(Airplane Model League of America, High School Club)

I agree to observe and abide by the regulations laid down by the National Aeronautic Association and the (your organization).

Signed.....

Please mail or bring this blank to the Director by (date)

For the scale-model entry blank the following form is suggested:

THE (Your organization) AIRPLANE MODEL FLYING MEET
.....(Your City).....(Date)

Director of the Scale Model Contest

Address

I wish to enter the Scale Model Division of the Airplane Model Meet to be conducted by the (your organization) on (date). I certify that the scale model was built by myself and that the wing span is exactly 24 inches.

My name is.....
(Write or print full name clearly)

My address.....
(Street) (City) (State)

Date of birth.....

I represent the.....
(Airplane Model League of America, High School Club)

I agree to observe and abide by the regulations laid down by the National Aeronautic Association and the (your organization).

Signed.....

Please mail or bring this blank to the Director by (date)

Distribution of Entry Blanks:

Entry blanks should be carried in the newspapers at least three weeks before the contest and should be run for a number of issues. Printed blanks should be distributed to manual training teachers, club leaders, playground leaders, Y.M.C.A.'s, Scout troops, and similar organizations. Scout troops will be interested because the building of a model plane that will fly is one of the requisites to an aviation merit badge. Playground departments are squarely behind model-plane building.

Contest Office:

Establish a contest office with a man in charge to receive entry blanks. Have entrants bring in their blanks — or mail them — to this office. All blanks should be in at least two days before the contest. At the time a boy brings his blank in, issue him a filled-out contestant's card and a contestant's badge. If you decide to charge a small entry fee, collect it at that time. It would be well, also, to issue the boy a sheet containing the rules, and a slip telling just where and when the contest will be held.

The man in charge of the contest office — when all entries are in — may rule off cards for the indoor and outdoor contests. Each card for the indoor contest should have room for ten names, and for the outdoor contest, six names. Use the form shown on page 236.

Each card represents an hour's work for one group of officials. If a boy is entering both contests, he should be entered on the earliest indoor card so that he may get through in time to compete in the outdoor.

INDOOR CONTEST SCORE CARD

Time: 9:00 A.M.

<i>Name</i>	<i>Age</i>	<i>Representing</i>	<i>Flights</i>			<i>Best Time</i>
Charles Chaplin	17	North High				
George Arliss	14	Lindy Club				
Herbert Pennock	16	Non-Stop Sq'dr'n				

The indoor cards may be given to the indoor contest director, and the outdoor card to the outdoor director. They, in turn, will issue them to the groups of officials at the time of the competition.

SELECTION AND DUTIES OF OFFICIALS

Hold a preliminary meeting of officials at least a week before the date of the meet in order to distribute to each a set of rules. Go over the rules with them. Hold a final meeting of the officials when all the entries are in. At that time, you might have to increase the force. Officials are organized into groups of three judges, one first starter and one second starter. The three judges and the second starter all have stop-watches.

Duties of the Officials:

It is the duty of the first starter to obtain the score card from the indoor contest director. He shall enter the time of each flight on this card and shall enter the number of delayed and unofficial flights in a manner to be explained later. If a blackboard is used, he shall have a clerk enter all flights upon the blackboard.

It is the duty of the second starter to notify each con-

testant when it is his turn to fly. In the indoor contest, each entrant is given two minutes in which to launch his plane, and, if he fails to launch it within that time, he is charged with a delayed flight. In the outdoor contest, the entrant is given five minutes. The second starter shall keep time on each entrant as he is called, to determine whether he launches his plane within the time limit. The second starter must be alert to prevent delays and see that entrants are ready to fly when the time comes.

It is the duty of the three judges to time each flight. They must clock the start when the model leaves the entrant's hands and clock the finish when the model touches the ground or disappears. They shall compare their times and report the correct time to the first starter.

How the Indoor Contest Operates:

The contest officially opens at 9.00 A.M. The first starter has obtained from the director a sheet bearing the names of ten entrants. He calls the roll of these contestants, informing them that they will fly in the order named.

The second starter then calls: 'Chaplin up! Arliss on deck!' At the same time he clicks on his stop-watch.

Chaplin, who has two minutes in which to launch his model after the second starter clicks the watch on him, finishes winding the motor. He launches his plane — not upon signal from the starter, but at his own discretion. The judges start their watches when the plane leaves the contestant's hand.

When the ship starts to descend, and it is apparent that the flight is nearly over, the second starter calls: 'Arliss up! Pennock on deck!'

He then starts his stop-watch upon Arliss to see that he doesn't take more than two minutes in which to launch his model.

When Arliss is getting ready, the judges take the time of the first flight — say 90 seconds; the first starter enters 90 upon his sheet and the blackboard.

Arliss's plane, unfortunately, starts to climb and then takes a dive for the ground. It flies less than 15 seconds, and therefore a delayed flight is charged against it.

The next man up, Pennock, fails to launch his plane within two minutes. He, too, is charged with a delayed flight.

This brings up Chaplin again, and Charlie makes a flight of 171 seconds. Arliss fails to get ready in time and is charged with a second delayed flight. Pennock then flies his plane 78 seconds. Chaplin makes a third flight of 140 seconds. Arliss, who has two delayed flights charged against him, again runs into bad luck when his rubber motor breaks in winding. This is his third delayed flight, and therefore one official flight is charged against him.

The third man had one delayed flight and one official flight. It is his turn now, and he flies his plane 18 seconds.

Then Arliss takes his turn and makes a flight of 110 seconds.

The third contestant makes a final flight of 150 seconds and Arliss's final flight is 89.

The score card would then read:

INDOOR CONTEST

Time: 9:00 A.M.

<i>Name</i>	<i>Age</i>	<i>Representing</i>	<i>Flights</i>			<i>Best Time</i>
Charles Chaplin	17	North High	90 DD	171	140	171
George Arliss	14	Lindy Club	D 78	110	89	110
Herbert Pennock	16	Non-Stop Sg'dr'n	D	18	150	150

The purpose of allowing three delayed flights before an official flight is charged is to give a boy every chance to realize the possibilities of his ship. The difference between a good flight and no flight at all is often a minor adjustment. Model planes are temperamental. It takes skill to fly them, and even the best model-builders often require two or three delayed flights before they get off a good one.

Judges should observe these cautions:

Be familiar with the rules; carry a copy of them in case of disputes.

Don't ask the entrant to launch his plane upon signal, but allow the boy — within the allotted two minutes — to launch when he pleases.

Don't require a boy to wind up his motor more than a half-minute before his turn to fly. A wound-up motor loses its life unless it is released almost immediately.

A group of indoor judges can handle no more than ten boys an hour. If there are two hundred entrants in your contest, it will take one set of officials twenty hours

to run them off. Four groups can do the job in five hours. Be sure, before the meet, that you've trained enough officials to handle the contest in the allotted time.

Each indoor score card, bearing ten names, represents an hour's work for one set of officials.

How the Outdoor Contest Differs from the Indoor:

The outdoor contest is run off in the same manner as the indoor. The duties of the officials are the same. The outdoor contest director will distribute to the first starter of each group of officials his score cards. Each score card bears six names — an hour's work. Be sure to have enough officials to handle your contest in the time at your disposal.

Use Scouts to Save Leg Work:

Since outdoor planes frequently fly more than a mile, each group of officials should employ two scouts. These scouts are equipped with flags. One is stationed a quarter-mile to windward of his group. The other is a quarter-mile beyond him. Then if the ship drifts so far that the judges cannot accurately gauge when its flight is terminated, the scouts can watch it and bring down their flags when the plane touches the ground. The dropping of the flag will be the signal for the judges to time the end of the flight.

How to Run off the Scale-Model Contest:

The scale-model contest bears no resemblance to indoor or outdoor flying meets. Scale models are not flown.

They are judged upon their resemblance to the man-carrying ship after which they're patterned, and neatness of workmanship.

Require entrants to bring or ship their scale models to the director at least two days before the meet. Display these models upon tables in a well-lighted hall.

The scale-model contest will prove to be an attractive exhibit in which the public will be interested.

The reason for requiring that all scale models shall have a wing span of just twenty-four inches is to facilitate the work of the judges. This size has been selected because it is the one satisfactory to the greatest number of builders.

Selection of Scale Model Judges:

Judges in this contest should have engineering training. They should be able to check measurements against a drawing and to judge originality and skill in workmanship. Aeronautical engineers or designers of famous planes would be ideal. In judging the models, score sheets, which have been prepared in advance, should be furnished the judges. The judges selected should be men familiar with the large replicas of the models submitted and their experience should have been such that they are competent to judge workmanship. An aeronautical engineer should know details of design, but a manual arts teacher probably would make the best judge on workmanship. A combination of these is the best bet.

How the Contest is Judged:

List the names of entrants on sheets of paper and assign

each name a number. To the propeller of each ship, attach a tag bearing the number corresponding to the proper name on the list. Judges should be supplied with rules, calipers, and scale drawings of the planes submitted.

The score card must be made up carefully, listing as many items to be checked as possible. These should be graded on a per cent basis to simplify the scoring. Since some boys will enter biplanes and others monoplanes, it is hard to judge the two ships fairly unless a definite balanced system of scoring is adopted and followed out. Any instructor will tell you that independently no two teachers would give the same score to a drawing even with the help of a measurement scale. Neither will two judges agree on the same score for a model without a rigid method of scoring. Watch that the showy model is not given first place because of general appearance. It may be completely out of scale and not even eligible to your last prize if correctly judged.

The score sheet should be divided into two major divisions under 'General Workmanship' and 'Fidelity to Scale.' Each division should be given fifty points. 'General Workmanship' should be divided into four minor headings: 'Neatness of Workmanship'; 'Amount of Detail'; 'Originality,' and 'Color and Finish Similarity.' 'Fidelity to Scale' is divided into subheads as: 'Fuselage'; 'Wings'; 'Landing-Gear'; 'Empennage'; 'Power Plant,' and 'Propellers.'

Each of the subheads is divided again to fit the plane to be judged. Under 'Fuselage' would be given such dimensions as are necessary to check the over-all length,

cross-sections, location of wings, tail surfaces, and landing-gear. While the judges were measuring these dimensions, they would also check the amount of detail under 'General Workmanship.' If the plane employed the same type of construction as employed in the large plane, it would be given more points than if it were carved out of solid wood. Again, if the model had movable controls operated from the cockpit, instrument panel, leather upholstered seats, or any of the other details found on the well-constructed scale model, it should be given proper credit. If a biplane is entered in the same contest with a monoplane, the dimensions of each of the biplane wings should count only half as much as the corresponding dimensions of the monoplane wings. That is, if the contestant makes an error in the span of one of his wings in the biplane, he might be marked off only two points, while the same mistake in the monoplane would rate a loss of four points. In this way, the contestant that chooses the more complicated model gets credit for it, while the other contestant isn't unfairly penalized.

By drawing up a rigid set of details, dimensions, and scoring points to be checked, in advance, with a numerical value set on each, all planes will be equally and fairly judged. These sheets should have not less than one hundred items to be checked. The list should be kept absolutely secret so that the contestants will not know on just what dimensions they are to be checked and so will strive for perfection.

Since the entire contest is judged on accuracy, the

drawings supplied to the contestants as well as judges must be true scale drawings. It is best to select a half-dozen ships of which drawings are available and confine the contest to these; otherwise the contest will be cluttered up with a nondescript collection of models made from outline drawings, photographs, and imagination. It is unfair to the contestants to permit these planes to be entered. Neither is it fair to allow a boy to make up his own drawings, as there is always the temptation to make the drawing correspond to the model rather than the model to the drawing.

Some boys will make up a drawing and send it into the manufacturer for his O.K. This O.K. is no assurance, as the average engineer will merely glance over the drawing, and if the general details are anywhere near correct will sign it and pass it on. Since it takes the better part of a day adequately to check such a drawing, you may be sure that your busy executive isn't going to have the time.

In order to avoid the above difficulties, the A.M.L.A., with the coöperation of the manufacturers, each year prepares three scale-model drawings of the most popular planes. These drawings are scaled down to the 24" wing span. The drawings are drawn to scale so that any part of them may be measured to get dimensions not shown. In addition to the drawings, there are shown photographs of the plane, and such details as the engine, landing-gear, and similar parts, that may offer difficulties to the boys. When these drawings are used in a contest, any other drawings should be accepted only if they contain as many dimensions as are found on the A.M.L.A. drawings.

The contestants should be warned to have their drawings passed on by the officials before starting their models.

Determining the Winners of all Contests:

So far, nothing has been said about Class A and Class B. In the National Contest, boys of sixteen years or older on June 1 are designated as Class A, and boys of fifteen or younger are Class B. It is provided, though, that younger boys may compete in Class A, while older boys may not step down to Class B. The two classes need not be run off separately! Nor need the younger boy designate which class he wishes to compete in. Run boys of all ages through the meet together.

When all results are in, the director of the meet will list the best times. In the outdoor division, for example, he may list results as follows:

	<i>Age</i>	<i>Best Time</i>
Mark Sullivan.....	18.....	290 seconds
Eugene Tunney.....	13.....	286 seconds
Robert Jones.....	20.....	214 seconds
Daniel McGrew.....	17.....	209 seconds
Sinclair Lewis.....	12.....	200 seconds
Herman Koehl.....	19.....	195 seconds
Frank Lowden.....	16.....	191 seconds
James Watson.....	17.....	190 seconds
Jess Sweetser.....	14.....	183 seconds
George Ruth.....	11.....	180 seconds
Paul Waner.....	10.....	175 seconds

THE NATIONAL AERONAUTIC ASSOCIATION

DEFINITION OF MODEL PLANES ELIGIBLE FOR RECORD
TRIALS AND RULES FOR MODEL PLANE CONTESTS

(No record is official until accepted by the Contest Committee
of the N.A.A.)

Hand-launched — An airplane is said to be hand-launched when it is released for flight directly into the air from the hands of the launcher. Airplanes even though equipped with landing-gears are eligible to try for hand-launched records.

Rise-off-the-ground (R.O.G.) — An airplane is said to be a rise-off-the-ground type when it has a landing-gear that will permit it to take off the ground under its own power. It must be constructed strongly enough to support the entire weight of the plane while taking off or landing. The owner must be able to demonstrate its usefulness by gliding the airplane to the ground from a height of not less than four feet and must land without damage to the landing-gear and without nosing over. The wheels should turn freely and be of such a size as to permit the airplane to taxi without difficulty on an ordinary wooden platform.

The minimum diameter of the wheels shall not be less than the following sizes:

Class A — $1\frac{1}{2}$ "

Class B — 1"

Class C — $1\frac{1}{4}$ "

Class D — $1\frac{1}{2}$ "

Class E — $1\frac{3}{4}$ "

Class F — 2"

Seaplane — A model airplane that can take off from and land on water. A seaplane shall demonstrate its seaworthiness by taxiing a distance of not less than ten feet on the surface of the water. It must also take off from the water under its own power at the beginning of the flight.

Amphibian — A model airplane that can either rise from and alight on land or water. It must meet the specifications of the R.O.G. and R.O.W. models without altering the landing gear. The time shall be the average of the best of the R.O.W. flights and the best of the R.O.G. flights out of three flights from the water (R.O.W.) and three from the ground (R.O.G.).

Pusher — A model airplane with the propeller or propellers in the rear of the main supporting surfaces.

Tractor — A model airplane with the propeller or propellers forward of the main supporting surface.

Indoor model — A model airplane designed primarily to fly indoors. The main supporting surface must have an area of less than 125 square inches of lifting surface.

Outdoor model — A model airplane designed primarily to fly outdoors. The main supporting surface must have 125 square inches or more of lifting surface. It shall also weigh at least one ounce for every fifty square inches of wing area. In other words, divide the wing area in square inches by 50 and the result is the minimum number of ounces the plane must weigh. This includes rubber motors and such extra weight as is necessary to be carried.

Fuselage model (*commercial*) — A model airplane with a built-up fuselage. When twisted rubber bands are used for the motive power, they must be contained within the fuselage. The minimum area of the maximum cross-section of the fuselage must correspond to the formula, $\frac{(L)^2}{10}$ where

L equals length of fuselage. The design of these airplanes must conform to good engineering practice and the fuselage must be stream-lined throughout. The fuselage shall be entirely covered except for an opening with an area of not over two square inches to allow access to the rubber motor.

Helicopter — A heavier-than-air craft rising vertically from the ground with no run and by action of a power-driven air

screw or vane. There shall be no lift except from the rotating surfaces.

Autogiro — A heavier-than-air craft which rises by virtue of the vertical component of the air on its freely rotating vanes on a vertical axis, supplemented by the pull of an air screw on a horizontal axis, similar to the airplane. There shall be no lift except from the action of the air on the rotating surfaces.

Ornithopter — A heavier-than-air craft which derives its lift from the flapping wings only. There are no subdivisions of ornithopters.

Scientific models — A model airplane is said to be a scientific model when the body of the model is composed only of a framework rather than an enclosed fuselage. Models using tubes to enclose their motors and those that do not fulfill the requirements of the fuselage type should be classed as scientific models.

True-scale model — A model airplane which is an exact replica of a man-carrying machine, every part being proportional in size to the corresponding part of the larger airplane.

Flying-scale model — A model airplane which is an exact replica of a man-carrying machine, every part being proportional in size to the corresponding part of the large airplane. The construction is such that by either shifting the wings or adding weight the model may be made to fly.

All model airplanes are divided into the following classes:

Class A — A model airplane is said to belong to this class when the area of its main supporting surfaces does not exceed 30 square inches.

Class B — A model airplane is said to belong to this class when the area of its main supporting surfaces does not exceed 65 square inches and is greater than 30 square inches.

Class C — A model airplane is said to belong to this class when the area of its main supporting surfaces does not exceed 125 square inches and is greater than 65 square inches.

Class D — A model airplane is said to belong to this class when the area of its main supporting surfaces does not exceed 150 square inches and is greater than 125 square inches.

Class E — A model airplane is said to belong to this class when the area of its main supporting surfaces does not exceed 280 square inches and is greater than 150 square inches.

Class F — A model airplane is said to belong to this class when the area of its main supporting surfaces exceeds 280 square inches.

No flying model may at any time drop any part of the airplane while in flight. The flight will not be counted, if it does so.

RULES FOR CONTESTS

Only duration contests are officially recognized

1. No restrictions on the design of the models except that they shall come under the classifications as provided in the N.A.A. definitions and classifications of Model Aircraft. No part of model may be dropped in flight.
2. Each contestant will be allowed a total of three official flights. He will be accredited with the greatest elapsed time made in any one of his three flights.
3. A flight shall be defined as a start which lasts for fifteen seconds or longer. Any flight under that or failure to fly in turn shall be considered a delayed flight. Three delayed flights during the contest shall be considered as an official flight.
4. A contestant will be allowed a maximum of three models, and he may use any or all to complete his official three flights.
5. Each contestant will draw a number, giving his place in rotation. He will be allowed two minutes within which to launch his model. Should he fail to launch his model in the time allowed he must withhold that official trial until his next turn in line and a delayed flight will be charged against him.

6. No contestant shall launch his model before receiving the launch-signal from the official starter. Any contestant doing so will be disqualified. All contestants must have their models ready for examination by the officials fifteen minutes before the starting time of the contest.
7. The judges shall agree beforehand as to the disposition of flights which end on obstructions.
8. In each event the winner of first place shall be the owner and builder of the model which has remained in flight for the longest time; and of second place, the second longest elapsed time, etc., provided the contestant has not been disqualified. In each event each contestant shall be allowed only the award to which his best flight entitled him.
9. No contestant may take part in any official model contest unless he is a member of some model airplane-building group recognized by the National Aeronautic Association, or a member of the N.A.A. itself. He must be the owner and builder of the models submitted. However, the design of the model may be obtained from other sources than his own. He shall be the builder of the entire model with the exception of the thrust bearings, thrust washers, and rubber motors, which may be purchased from other sources.
10. Any contestant breaking the rules of the race, or subsequent ones which may be sent out in writing, shall, upon the recommendation of the officials, be disqualified. Hand-launched models are not disqualified if broken in landing.
11. No protests shall be considered unless presented to the contest committee in writing within twenty-four hours after the finish of the race.
12. The judges shall decide before the race the minimum number of entrants necessary to a contest.
13. There are no categories for lighter-than-air craft due to the danger of gases used in their inflation.
14. No provision for speed records has been made, for it has been found that speeds in excess of 50 m.p.h. are attained, and uncontrolled models flying above this speed are extremely

dangerous and almost impossible to time accurately. We discourage them as a part of contests.

15. Altitude records are not kept because of the difficulties in obtaining the results accurately.
16. In order to be eligible for model records and/or to participate in any contest, all contestants must be less than twenty-one years of age and must be a member of a model airplane organization recognized by the N.A.A. or of the N.A.A. itself.
17. The following officials shall be present for the conduct of a model airplane meet:
 - (a) At least three timers, not related in any way to any contestant, timing each flight.
 - (b) One recorder.
 - (c) One starter.
 - (d) Additional assistants may be used as circumstances warrant.
18. The terrain shall not vary as to difference of level more than standard practice for landing-areas of airports.
19. All records eligible for recognition by the N.A.A. either must be run in sanctioned meets or under specific directions of the contest committee of the N.A.A. This committee shall be the final judge in the interpretation of all rules whatsoever of all races run by recognized model groups.
20. Contestants shall be divided into two groups according to age. Those up to and including sixteen years of age shall be known as the junior group; those from seventeen but not older than twenty-one shall be called the senior group. There will be separate categories of records for each group.

INFORMATION REQUIRED FOR APPLICATION FOR RECORD FOR RUBBER-DRIVEN MODEL AIRCRAFT

Approved by.....

To: Contest Committee
National Aeronautic Association
Barr Building
Washington, D.C.

Report on a model aircraft record trial conducted in accordance
with N.A.A. regulation:

Name..... Date of Birth..... Age.....
Address..... City..... State.....
Model Flying Club represented.....

Description of Model Aircraft

Type of Model..... Class.....
Span..... Chord.....
Area of supporting surfacessquare inches.
Number of Propellers..... Power (Kind).....
Distance between front bearing and rear hookinches
Weight of modelounces

I certify that I personally constructed the model aircraft above
described.

.....
(Signature of applicant for record)

Timers' Report

Date of Trial..... Place.....

We, the undersigned Timers and Observers, certify that we have
personally checked the dimensions of the above described model

plane and find them correct. The performance is certified as follows:

Duration..... Seconds

Distance (calm air)..... Feet

.....
(Chief Timer) (Address)

.....
(Assistant Timer) (Address)

.....
(Assistant Timer) (Address)

Forward photograph of applicant for record and scale drawing of model with each record report.

RULES FOR THE STOUT INDOOR CONTEST

SANCTIONED BY THE NATIONAL AERONAUTIC ASSOCIATION
UNDER RULES OF THE FÉDÉRATION AÉRONAUTIQUE
INTERNATIONALE

THE William B. Stout trophy shall be competed for annually by members of the Airplane Model League of America, or other nationally recognized model aero clubs using hand-launched model airplanes, driven by rubber strand motors. The trophy shall be awarded each year to the club, body or chapter represented by the entrant who builds and flies the winning model, and this body shall be entitled to the possession of the trophy until one month prior to the next contest, at which time the trophy shall be returned to the contest committee of the A.M.L.A. Suitable bond or guarantee for its proper care and return shall be required from each and every person or organization into whose possession the trophy shall be delivered.

The trophy will become the permanent possession of any club, body, or chapter that wins it three times.

CONDITIONS OF THE CONTEST

1. No restrictions on the design of the model except that it shall have a distance between the propeller bearing and the motor hook, fastened to the opposite end of the motor stick, not to exceed fifteen inches.

All models must be hand-launched, and the only motive power be derived from the use of rubber strands.

2. The contest will be for duration. A contestant will be allowed a total of three official flights. He will be accredited with the greatest elapsed time made in any one of his three flights.
3. A contestant will be allowed a maximum of three models, and he may use any or all to complete his official three flights.
4. No contestant shall launch his model before receiving the launch-signal from the official starter. Any contestant doing so will be disqualified. All contestants must have their models ready for examination by the officials fifteen minutes before the starting time of the contest.

Each contestant will draw a number, giving his place in rotation. He will be allowed two minutes within which to launch his model. Should he fail to launch his model in the time allowed he must withhold that official trial until his next turn in line and a delayed flight will be charged against him.

5. Any flight under fifteen seconds and every failure to fly in turn shall be considered a delayed flight. Three delayed flights will be considered an official flight.
6. The finish time will be taken when the model strikes or lands on any object preventing further flight.
7. The winner of first place shall be the owner and builder of the model which has remained in flight for the longest time; and of second place, the second longest elapsed time, etc., providing the contestant has not been disqualified. No individual will be allowed more than one cash prize; each contestant will be allowed only the prize to which his best flight entitles him.
8. No contestant may take part in this contest unless he is a

member of the Airplane Model League of America or some nationally recognized model aero club using hand-launched model airplanes, driven by rubber strand motors. He must also be the owner and builder of the models submitted. However, the design of the model may be obtained from other sources than his own. He shall be the builder of the entire model with the exception of the thrust bearings and thrust washers which may be purchased from other sources.

(*Note: Users of A.M.L.A. kits are eligible.*)

9. Any contestant breaking the rules of the race, or subsequent ones which may be sent out in writing, shall upon the recommendation of the officials, be disqualified. Models broken upon landing will not be disqualified.
10. No protest shall be considered unless presented to the contest committee in writing within twenty-four hours after the finish of the race.
11. Minimum number of contestants eight. Maximum number of contestants twenty-five. (This applies only to the finals.)

RULES FOR THE MULVIHILL OUTDOOR CONTEST

SANCTIONED BY THE NATIONAL AERONAUTIC ASSOCIATION
UNDER RULES OF THE FÉDÉRATION AÉRONAUTIQUE
INTERNATIONALE

(a) The trophy shall be perpetual and competed for annually by members of the Airplane Model League of America, or other model aero clubs recognized by the National Aeronautic Association, using hand-launched model airplanes, driven by rubber strand motors.

(b) The trophy shall be awarded each year, to the club, body, or chapter represented by the entrant of the winning model, and this body shall be entitled to the possession of the trophy until one month prior to the next succeeding contest, at which time the trophy shall be returned to the National Aeronautic

Association; suitable bond for its proper care and return shall be required by the donee (the N.A.A.), from each and every person or organization into whose possession the trophy shall at any time be delivered.

CONDITIONS OF CONTEST

No restrictions on the design of the model except that it shall be hand-launched and the only motive power will be that derived from the use of rubber bands.

CHARACTER OF CONTEST

The contest shall be for duration. A contestant will be allowed a total of three official flights. He will be accredited with the greatest elapsed time made in any one of his three flights.

NUMBER OF ENTRIES PER CONTESTANT

A contestant will be allowed a maximum of three models, and he may use any or all to complete his official three flights.

METHOD OF STARTING

No contestant shall launch his model before receiving the launching-signal from the official starter. Any contestant doing so will be disqualified.

All contestants must have their models ready for examination by the judges by 9.00 A.M. Contests will start at 9.30 A.M. Judges shall select the place of starting previous to contest. Each contestant will draw a number giving his place in rotation of starting. The same rotation will follow until each contestant has completed his three official flights. The time of starting of each contestant will be posted ten minutes in advance.

He will be allowed five minutes within which to launch his model. Should he fail to launch his model within the time allowed, he shall be charged with a delayed flight and he must withhold that official trial until his next turn in line. Any flight

under ten seconds will not be official and will count as a delayed flight. Three delayed flights shall count as an official flight.

FINISH

The finishing time will be taken when the model first touches the ground after being launched or when it passes out of sight of officials.

WINNERS

The winner of first place shall be the owner and builder of the model which has remained in flight for the longest elapsed time, and of second place the second longest elapsed time, etc., providing the contestant has not been disqualified. No individual will be allowed more than one cash prize. To distribute the prizes more evenly, each contestant will be allowed only the prize to which his best flight entitles him.

QUALIFICATIONS

No contestant may take part in the contest for this trophy unless he is a member of the Airplane Model League of America or other model Aero club recognized by the N.A.A. and in good standing. He must also be the owner and builder of the model submitted. However, the design for the model may be obtained from other sources than his own. He shall be the builder of the entire model with the following exceptions: Propellers, motor bearings and propeller shaft; also such other small metal fittings as may be used in the construction of the model may be purchased from outside sources.

DISQUALIFICATIONS

Any contestant breaking the rules of the race, or subsequent ones which may be sent out in writing, shall, upon recommendation of the judges, be disqualified. Models broken upon landing will not be disqualified.

PROTESTS

No protest shall be considered unless presented in writing to the Contest Committee within twenty-four hours after the finish of the race. (F.A.I. Rules, 78, 79, 80.)

RULES FOR THE SCALE MODEL CONTEST

The trophy shall be competed for annually by members of the Airplane Model League of America or other nationally recognized model airplane clubs building exact scale models.

CONDITIONS OF CONTEST

1. There will be no restrictions as to the design of the ship except that it must be an exact replica of a man-carrying airplane and have an exact wing span, including ailerons, of twenty-four inches.

The models do not have to fly, nor need any parts such as propellers, wheels, etc., be movable. Neither is it necessary to use the same material in construction as employed on the large ship.

2. The contest will be for workmanship, originality in obtaining the desired resemblance to the man-carrying ship, the exactness to which the model is scaled and any other points which are, in the opinion of the judges, important in such a contest.
3. Each contestant will be allowed to submit one model and unless the model is made from drawings previously checked by the Contest Committee of the A.M.L.A., it must be accompanied by a drawing giving all necessary dimensions, air-foil sections and such other details as may be considered necessary by the judges in order to construct a model. This drawing must be one supplied by the manufacturer of the airplane, after which the plane was modeled, or be accompanied by a letter from the company building the plane, stating that the manufacturer or his representative has checked the drawing and found it to be correct.

4. All planes and drawings must be in the hands of the Contest Committee at least two weeks before the date of the contest.
5. The winner of first place shall be the owner and builder of the model which in the judgment of the officials is the best example of workmanship as defined by the rules, and of second place the next best example of workmanship, etc., providing the contestant has not been disqualified. No individual will be allowed more than one cash prize; each contestant will be allowed only the cash prize to which his place entitled him.
6. No contestant may take part in this contest unless he is a member of the A.M.L.A. or some other nationally recognized model airplane club. He must be the owner and builder of the entire model submitted.
7. Any contestant breaking the rules of the contest or subsequent ones which may be sent out in writing, shall upon the recommendations of the officials be disqualified.
8. No protests shall be considered unless presented to the Contest Committee in writing within twenty-four hours after the finish of the contest.
9. Minimum number of contestants eight.

CHAPTER XXV

GLIDERS AND GLIDING

Author's note: It would be a mistake to leave out any mention of gliding in a book of this character in face of the steady growth of the interest in this sport in America. To-day, gliding clubs are being formed throughout the country. The following chapter on gliding is taken from a bulletin published July 1, 1930, on 'Gliders and Gliding' by the United States Department of Commerce, Aeronautics Branch. The author feels that it covers the subject as fully as possible in the space available. It has the added advantage of having the endorsement of the Department, and, of course, that stamps it as being the best information available on the subject.

THE glider and the art of gliding abound in historical significance. But it was not until the early nineties that the glider took on serious proportions. At that time, civilization had progressed to the point where farsighted individuals saw the age of human flight in powered craft just beyond the horizon.

While the glider was in existence in one form or another prior to 1890, the events that followed the experiments with gliders in the nineties and which culminated in the first flight of a powered machine carrying a human being were of such outstanding importance that it would seem the art, science, and sport of glider operation may well be dated back to just a few years before the dawn of the twentieth century.

Otto Lilienthal, of Germany, one of the outstanding

pioneers in gliding, between 1890 and 1896 made many successful flights with gliders, covering distances as great as one thousand feet from the point of take-off. With the glider, he was in search of what we have to-day — the airplane. The glider was regarded as the stepping-stone in the eyes of those pioneers, and a correct and reliable stepping-stone it proved to be.

While Lilienthal was conducting glider experiments, others interested themselves in this form of flying. Among those whose work is a matter of history are Percy S. Pilcher, of England; Voisin and Farman, of France; and John James Montgomery, Octave Chanute, and A. M. Herring, of the United States.

In 1900, the Wright brothers constructed and flew gliders to aid them in their search for the realization of their dreams. The Wright gliders appear to have been the first in which the landing gear was employed. These gliders used skids which are standard equipment on many of the present-day types. In employing the skids, the Wrights obviated the necessity for using the feet in landing, which was a feature of the 'hang type' then in vogue. The 'hang type' called for the suspension of the glider pilot from his armpits, in order that he could use his feet as power for taking-off, as a means of alighting on the earth, and as a means of balance in the air.

In 1905, John James Montgomery was conducting experiments with gliders which embodied complete control surfaces, such as warped wings, rudders, and elevators. Montgomery's experiments with gliders in general began about 1880.

A distinctive feature of the work of Montgomery was the method he adopted for launching the gliders. He took off from hot-air balloons. Thus, the feat of Lieut. Ralph S. Barnaby, United States Navy, of being launched in a glider from the rigid airship *Los Angeles*, was not entirely without precedent. Montgomery is credited with having taken off from balloons at altitudes ranging from one thousand to four thousand feet, while other glider advocates were content to use hills as their starting point.

Montgomery, aside from deriving certain remuneration from his gliding activities at public exhibitions, used the glider for studies in aerodynamics.

In 1911, Orville Wright returned to Kitty Hawk with a glider to conduct further flight experiments on automatic stability devices for airplanes. In connection with these flights, he established a duration record of nine minutes and forty-five seconds, which remained unbroken in this country until 1928.

In 1912, a glider camp was established at Rhön, Germany, but it was not until after the World War that widespread activity took place there. The hill which was the site of the first camp now is marked by permanent buildings, housing schools and accommodations for glider enthusiasts.

Between 1912 and 1914 in the United States there was some activity in gliding. Numerous plans and specifications became available for the manufacture of biplane gliders and at least one company established itself on record as manufacturing these craft. Virtually all of the plans were for the 'hang type' glider.

The World War served to detract interest from gliding which did not resume in the United States until 1922, when a glider club was formed at Massachusetts Institute of Technology. One of the members qualified to participate in the annual Rhön competition, which marked the turning point in gliding accomplishments. Heretofore flights had been comparatively brief in duration, but during the competition they were extended into periods of hours.

Once again the gliding activity in the United States lapsed only to be revived again in 1928 with the arrival at Cape Cod of several German glider experts, one of whom, Peter Hesselbach, established a duration record of more than four hours, thereby breaking Orville Wright's record of 1911.

By 1930, the glider movement in the United States was well under way. From ten to fifteen companies were manufacturing gliders; glider clubs had been formed and still are being organized; the record flight of Hesselbach at Cape Cod was broken by Bowlus, an American, with an American designed and built glider (soaring plane or sailplane); a glider was launched from the Los Angeles, and a glider was towed across the continent by an airplane. An added impetus was given to the movement by the glider flights of Colonel Charles A. Lindbergh.

Gliding is great entertainment and great sport. But it goes farther than that. It offers a stepping-stone leading to subsequent training in the engine-driven plane. Specifically, primary gliding is a training for advanced stages of gliding and the most difficult and yet most fascinating of all phases of this activity — soaring.

When the glider pilot graduates into soaring, he enters the field of meteorology, topography, and expert airmanship. To remain aloft for hours at a time in a motorless heavier-than-air aircraft calls for a working knowledge of these subjects. The rewards for the efforts expended are the accomplishments.

It took the glider pilots at the Rhön five years to learn to soar for several hours. They developed cloud flying by utilizing the currents peculiar to cumulus clouds. These currents have an upward trend, culminating in the clouds. Immediately beneath the clouds the movement is sufficient to enable the motorless plane to hold its altitude.

The other type of soaring flight calls for the utilization of ground currents found over rough terrain. A skillful pilot may employ these currents as they rise over the edge of a hill or ridge to great advantage and may 'crab' along the peak of the hill or ridge, back and forth to his heart's content.

A glider may be described as an airplane without engine and reduced to the simplest elements. There are three types: (1) primary glider, (2) secondary glider, and (3) soaring plane.

The primary glider is just what its name implies. It is the starting point, the beginning.

The secondary glider is for those who have achieved the lessons taught by the primary. It has a better gliding angle, is of lighter construction and will not stand the abuse that the primary is subjected to during the training periods. Whereas the primary glider has a gliding angle of about eight to one (it will glide forward eight feet while

losing one foot of altitude), the secondary is credited with having a gliding angle of from twelve to fifteen to one.

The third type is the soaring plane, sometimes called soarer or sail plane. This craft, of refined construction and extremely light in weight, has a gliding angle of about twenty to one. These planes are used in record-breaking attempts for duration and altitude.

Flight instruction on motored aircraft is treated with great respect. Many weeks are usually devoted to practice flying before the student is eligible to take the Department of Commerce examination for a private pilot license.

Generally there is no difference between being aloft in a glider and an engine-driven plane, except that in the latter case the student in the early stages of training, has an instructor present to correct any serious mistakes.

Owing to the limited load-carrying capacity of most types of primary gliders, instructors cannot go aloft with the glider student. However, this condition is expected to change as time goes on so that students will have personal instruction in the air.

Pending the arrival of the day when a glider student will not have to go aloft alone he should be thoroughly drilled in the manipulation and significance of the controls before making his first flight. His first trip in the air is no occasion to learn for the first time what will happen if the stick is pulled back, or pushed forward, or moved to the right or left.

There are three methods of glider training which may

be followed with success as long as airworthy gliders and competent instructors are involved. One is to launch the glider by means of an elastic cord from a small hill; another is to launch it from a flat surface by the same method; and the third is by automobile towing from a flat surface. The launching of gliders from water by speed boats is somewhat similar to automobile towing. Towing of gliders by aircraft is prohibited except by special permission from the Secretary of Commerce.

The launching of gliders from a hill by the elastic-cord method is perhaps the most elementary and yet most satisfactory method of teaching beginners. Particularly is this true if the glider club or group participating in the activity is fortunate enough to obtain the use of a hill with a gradual slope. In this event, the result is quite comparable to sliding down hill except that the glider always is above the ground, provided of course the gliding angle is not less than the grade of the hill.

To be launched by the elastic-cord method from a hill requires the participation of several persons. The elastic cord is secured at a point directly in the nose or bow of the glider fuselage framework and is subject to automatic release when the tension on the cord is relaxed. It then is carried out in a V shape, the glider being at the apex of the V. The rear of the glider either is held down by man power or is tied to a post driven in the ground with a snubbing device that can bring about its quick release.

On each end the V-shape cord, there should be not less than three persons. On a given signal, they walk away from the glider, stretching the cord as they go. When the

desired elasticity of the cord is approached, the person in command of the flight (either the instructor or the pilot at the controls) shouts, 'Run!' At about the same time the forces holding onto the rear of the glider are released, the glider is catapulted into the air as the crew runs with the cord and the glider takes off straight ahead with no danger of alighting in the midst of the crew, who by their V-shape formation have moved far out of the direct course contemplated by the glider pilot.

No sooner is the pilot in the air than his thoughts turn to making a landing. If the gliding angle of the craft is high, and the slope of the hill compares somewhat favorably with that angle, the glide will be longer than if the launching took place on a flat surface. In cases of a straight flight, the glider launched from a hill will land at an altitude below the point from which it took off. In launching from a flat surface, obviously the operation is reduced to a sudden climb into the air and then a descent.

In flat country, various methods have been and constantly are being devised for the launching of gliders in addition to the hand-operated elastic-cord practice as heretofore described. These include the employment of an automobile to stretch the cord to the desired tension; devices for holding down the tail which automatically release the glider when a certain tension is reached; and a 'sling shot' method whereby the glider, attached to an elastic cord with ends made fast to the ground, is pulled back and released into the air. In both the mechanical and manually operated devices, there may be found provisions for regulating the amount of tension and thereby

controlling, to a great degree, the force which catapults the glider into the air. This in turn gives a certain amount of control over the altitude or distance the glider is to fly.

Elastic-cord launching offers great possibilities for glider training without any unusual hazard. Because it is primary and elementary, it should not be ignored or passed over lightly. Especially in the case of a person with no previous heavier-than-air aircraft experience, this method constitutes the very foundation for the future stages of glider flying into which the student wishes to progress.

Automobile towing offers greater possibilities for longer time in the air, more manipulation of the controls and the attempt at slight turns and banks as proficiency increases. In towing, the student should be taught the smooth and easy use of the controls by being towed just under flying speed. As the student becomes proficient, the speed of the automobile should be increased gradually until the glider is from three to six feet off the ground and then decrease until the glider again touches earth. This practice is repeated until the student has the 'feel' of flying and landing.

The driver of the car always should slow down when the glider fails to follow the path of the car either on the ground or in the air. At no time should the driver of the car permit the student to hold an excessive angle of climb without stopping to correct him.

Glider always should be towed directly into the wind. Immediately before the flight is to start, the slack should be taken out of the cable or tow line to prevent breakage

or jerking the glider. While towing, the driver of the automobile should be careful to shift the gears of the car smoothly in order to maintain steady acceleration. A glider should never be towed at excessive speeds.

Of the three general methods of glider launching, automobile towing should be given the most careful consideration as there is greater liability of damage to the craft or injury to the pilot through this method.

Automobile towing should not be undertaken unless there is some one in the towing car who has had experience with this form of launching. This experience is necessary because the towing car is in an excellent position to regulate the flight of the glider, by slowing down, speeding up, or stopping altogether. The occupants of the car bear as close a relationship to the glider pilot as the instructor who rides in an engine-driven plane with a student.

Airworthy gliders under the supervision of experienced glider pilots who are competent to give instruction, serve to bring about a realization of all the good points in gliding activities. Without competent supervision and instruction gliding may become exceedingly dangerous even though no doubt exists as to the glider's condition of airworthiness.

If gliders are to be constructed by individuals, clubs, or other groups interested in gliding, a skilled aeronautical designer and constructor should be obtained to supervise the work from the drawing board to the test flight. If such assistance is not available, then the gliders should be acquired from reputable and reliable sources.

The primary gliders should be acquired first, unless the prospective purchasers have qualified on this type. It is a waste of time and money to construct the lighter types, owing to the hard usage to which they are subjected during training.

In purchasing gliders, it would be well to determine in advance if they have been granted approved-type certificates by the Aeronautics Branch of the Department of Commerce, or if they are eligible for license. If they have the approved-type certificate or are eligible for license, they, therefore, bear the Government's stamp of approval as to airworthiness.

Once all doubt has been removed as to the airworthiness of the gliders, careful consideration should be given to the competency of the instruction. Successful gliding cannot be accomplished without a close coördination of the two essential elements — airworthy gliders and competent instruction.

The glider movement in the United States is attracting the attention of hundreds of people, many of whom are in search of information concerning the construction, operation, and licensing of gliders, as well as information involving instruction, student permits, and glider pilot licenses.

This condition, together with the fact that more than a score of States require Federal licenses for aircraft and airmen, has caused the Aeronautics Branch of the Department of Commerce to recognize the existence of a need for Federal interest in gliders and gliding. This interest takes the form of new regulations governing the licensing of gliders and glider pilots.

In drafting the new regulations the department has made a sincere effort to further the gliding activity in all its phases. The regulations aim to provide for the elimination of probable sources of danger in gliding, which always will exist unless there is intelligent care and attention given to the construction, maintenance, and operation thereof.

The regulations embody the following provisions:

Three classes of gliders will be considered eligible for license and will be licensed upon passing an inspection by the Department of Commerce. The three classes are:

1. (a) Gliders manufactured under approved-type certificates. This corresponds to the present procedure involving the licensing of airplanes which are built under approved-type certificates.

(b) Gliders constructed by any one, provided they are built in accordance with specifications and designs which have been previously approved by the Department of Commerce.

2. Gliders not manufactured under approved-type certificates but which meet the requirements for such a certificate.

3. Gliders not included in either class 1 or 2 will be eligible for license provided they pass a visual inspection by the Department of Commerce as to design, materials, workmanship, and flight characteristics, and provided they are manufactured prior to October 1, 1930.

Gliders under class 1 (a) are those manufactured in quantities by holders of approved-type certificates for the type of gliders they are building. Such gliders shall be

exactly similar in specifications, design, and workmanship to the type approved by the Department of Commerce.

Gliders under class 1 (b) are those manufactured by private owners or others who have followed previously approved specifications and design, such as gliders manufactured from the drawings of an approved-type glider, provided, of course, the holder of the approved-type certificate sees fit to distribute such drawings.

Gliders manufactured under class 2 are those which meet all of the minimum requirements for an approved-type certificate, but for which a certificate is not desired because quantity production is not planned.

Gliders under class 3, include those built by individuals and clubs with or without previously approved designs, provided they have been manufactured prior to October 1, 1930. Their eligibility for license will be determined by a visual inspection of the design, materials, workmanship, and flight characteristics according to a 'rule-of-thumb' method which has been devised by the department. Gliders so constructed after October 1 will not be considered eligible for license.

Three types of glider-pilot licenses are provided for — student, noncommercial, and commercial.

Glider-student permits, authorizing the holder to receive instruction and to solo licensed gliders while under the jurisdiction of a licensed glider pilot, will be issued by Department of Commerce inspectors and department divisional offices upon application. No physical or written examination will be required. A form has been drafted which is both an application and student permit,

a perforation permitting their separation. These forms may be obtained from any Department of Commerce inspector or divisional office.

The noncommercial glider license will serve the group that is desirous of operating gliders only for sport and pleasure. This license parallels, to a degree, the private airplane pilot license. The only examination required for this license will be a flight test which will consist of a minimum of three flights including moderate banks in either direction. Applications for noncommercial glider licenses may be made on regular pilot application forms obtainable from department inspectors or divisional offices.

The commercial glider pilot license will be issued to all applicants physically qualified who successfully accomplish the flight test involved. Applicants for the commercial license are required to pass a physical examination the same as is now required for the private airplane pilot license. There is no written examination.

The flight test for the commercial glider pilot license, in addition to normal take-offs and landings, includes a series of general and moderate banks, 360° turns and precision landings.

The glider pilot licenses will be issued to all grades of airplane pilots upon a satisfactory completion of the tests involved.

Applications for the commercial glider-pilot license also may be obtained from department inspectors or divisional offices.

Glider and glider pilot licenses are mandatory in States requiring Federal licenses for aircraft and airmen.

CHAPTER XXVI

THE A.M.L.A. SOARING GLIDER

HERE'S a model that can be taken out in any open lot and by hand launching get the maximum performance. But if you want to see a real soaring glider, take it to the top of a high hill with the wind blowing up the slope. You won't have to launch it here, just hold it aloft and it will do the rest. In test flights, it will rise as high as thirty to forty feet directly above the starting-point, head into the wind and away it will go for sixty to seventy seconds flights.

One of the most noticeable features of the 1930 National Indoor Contest was the effect gliding has had on the design of the indoor models. Most of the models showed a trend toward wings with high aspect ratio and lower angle of incidence. This, with the glider type empennages, clearly set them apart from the designs of former years. These models were not from any one section of the country, but came from all sections. Because of this interest, it was decided to select a real soaring glider as the first of the 1930-31 series of A.M.L.A. models.

In order to get just the right model, the manufacturers of soaring gliders were appealed to for drawings and designs. Exact scale models with built-up wings and fuselages were built and tested. Some of these models required two and three days to build but none quite came

up to expectations. While working on the design of the larger models, a number of small wooden working models were made. One of these models, in the tests, not only out-performed all the others, but to the surprise of every one, outclassed the big built-up models. In fact, it performed so well it was chosen to replace the more complicated built-up models.

Before starting to build your model, study the design carefully. Notice that it is built after the German gliders. The basswood fuselage is used for a purpose. It out-performs the lighter balsa fuselage and does not require a nose weight due to the fact that the greater part of the weight is in front of the wing. The kit to build this model contains everything you need from the wood to the two sizes of sandpaper. Your jack-knife is the only tool necessary. You will find the soarer is an easy plane to start with. The kit will just about build itself.

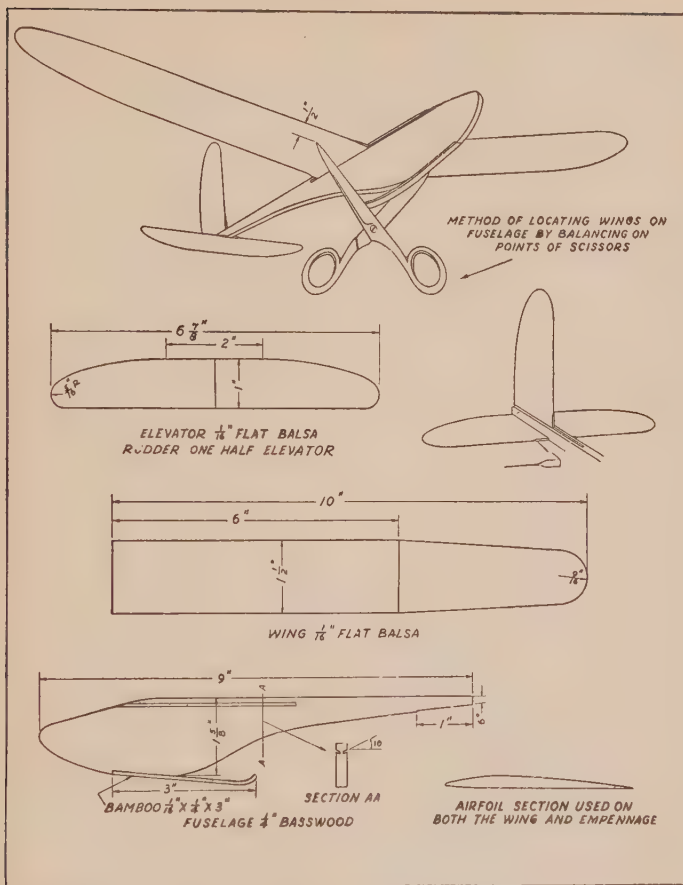
If you have purchased an A.M.L.A. kit, you will find a piece of basswood $1/4 \times 1\ 3/4 \times 9\ 1/8''$, slotted for both the wings and empennage. Notice that the wing slot is cut at angle. This is shown in section AA in the drawing. That is, if the finished fuselage were to be cut in two on the line AA, the end of the piece would look like drawing marked section AA. These slots are for the wing and since each half fits real snugly, automatically determines the dihedral angle. If you are building your model with materials other than that found in the A.M.L.A. kit, you will probably have to decide on another method of attaching your wings. Few boys will have the proper equipment for cutting slots at an angle as shown

in the drawing, and since both slots must be identical, free-hand methods are to be discouraged.

Notice that the rudder is set into a groove in the fuselage. This insures a rigid, accurate setting of the rudder. A rudder set at a slight angle will spoil the performance of your glider. Notice, too, that the elevator is set at an angle of six degrees to the wing slot. This angle is taken care of on the fuselage in the kit by a slot cut at the correct angle.

Let us begin the construction by cutting the fuselage to the correct shape. Each A.M.L.A. kit is supplied with full-size patterns of the wings, elevator, and fuselage. These may be cut out and used to trace around in order to get the correct shapes. Notice that the fuselage block is cut away to permit the elevator and the tail skid to set in flush with the adjoining surface. This will help to prevent these members from being broken or torn loose from the fuselage. When you have your fuselage carved to the line, take the coarse piece of sandpaper, wrap it around a small block and finish the edges smooth.

The skid is made from a piece of bamboo $1/16 \times 1/4 \times 3''$ long. This should be finished smooth so that it will just fit even with the bottom of the fuselage. The rear end is rounded to improve the looks and then bent upward slightly. Notice the drawing. Bamboo can be bent easily when heated just below the burning point. An electric soldering iron will simplify this operation for you. You will find that the skid will often add thirty or forty feet to the flight of your glider as the plane will land, slip along on the skid for a few feet and take off again.



NO. 36. A.M.L.A. SOARING GLIDER

Although the elevator may be cut from 1/16" balsa and left flat, the model will perform better if a thin airfoil section is sanded into the surface as shown in the drawing. Notice that both the elevator and rudder are left flat at the points where they intersect the fuselage. This will permit neater joints than could be obtained without cutting the outline of the curve into the stick. The rudder is streamlined by sanding, see the two sections shown in the drawing. The plan-form (outline) of the elevator is clearly shown in the drawing. This can be drawn on the flat stock and then the parts shaped in the same manner as used in shaping the fuselage. The rudder is the exact size and shape of one half the elevator.

The sections are obtained by sanding first with the coarse and then with the fine sandpaper. Be sure to wrap your paper around a small block before using.

When the elevator and rudder are finished, they should be assembled to the fuselage. Care must be used to make sure that they are set squarely with one another and to the fuselage. If you have followed directions carefully, your elevator and rudder should look like the sketch. Be sure to use plenty of cement in assembling and allow not less than an hour for it to harden. A glider is subject to much greater strains than an airplane because of its weight. A poorly made joint will give with the first nose dive.

The wings are next in line. If you have a kit just lay your full-size pattern on your blank, trace the outline with a pencil and cut to shape. A sharp knife will do the trick. Some boys prefer to cut the curves with a razor

blade. It is important to get each wing exact. When the tips are formed, they can be improved by sanding, just enough to remove the rough edges. If you haven't a kit, make a full-size drawing of the wing on a piece of thin cardboard and using this as a pattern, proceed as above.

The wings may be left without attempting to form an airfoil section, but the glider with a thin airfoil section will out-perform the flat one, everything else being equal. It is important to remember that in sanding a section on the wings, we automatically make our wings into a right and left. That is, while the wings are flat, they may be used on either side but just as soon as we sand an airfoil section into the wing with a definite leading and trailing edge, they will fit only one side. Watch that you don't make them identical. Slip your wings into the slot and mark the leading edges with a pencil on the upper sides. This will insure you against making the mistake of making similar wings. To sand the wings, first sand the leading edge. Try to round the upper edge to the shape shown in the drawing then the lower surface at the leading edge. Next, lay the wing flat on the table with the trailing edge of the wing even with and parallel to the edge. Now sand the slope to the trailing edge. Of course, all the sanding is done with the sandpaper wrapped about a small wooden block. Notice that the thickest part of your wing lies about one third (one half inch from the leading edge) of the width of the wing from the leading edge. The wing curves from that point to the trailing edge. It isn't advisable to make too thin an edge either on the leading or trailing edge. A glider in flight will hit many obstruc-

tions such as poles, trees, and wires. Thin balsa will chip and break, spoiling your plane. Notice that the lower surface of your wing is flat except near the leading edge. This surface should be sanded smooth with the fine sandpaper. Smooth surfaces on your model will improve the performance of the finished soarer.

Notice how long the wing slot is on the model shown in the drawing. This slot is cut at a predetermined angle so that the wing will have dihedral angle of ten degrees. The slot was made long to permit the balancing of the model as shown in the drawing. By setting the wings into the slots, you will find they fit snugly and will stay in place while balancing, one can check the proper location of the wings absolutely accurate. The plane should balance at points from $7/16''$ but not more than $1/2''$ from the leading edge. Notice how the plane is set on the points of a pair of shears. The elevator must be level with the wing when perfect balancing is obtained. You may have to try several times before you get the right location for your wing. A line drawn parallel to and $7/16''$ from the leading edge along the lower surface of your wing, will help you to locate the proper points easily. With the points of your scissors along this line, the plane should balance perfectly when the wings are set properly. If the tail goes up, move the wings forward; if the tail goes down, move the wings back until the proper place is located. Mark this point on the fuselage, remove your wings, squeeze the slot full of cement at the point where the wings set and force them into place. Check it again for balance and also make sure that both wings are set at

the same angle. This may be done by laying the fuselage against the side of any square edge such as a desk top with the lower edge of the wing against the edge. Now, by measuring first the tip of one wing from the surface and then the tip of the other, we can check very accurately. Both tips must be the same height or the glider will not glide correctly, but will tend to bank to one side or the other. It is a good idea to set the glider on the table with two small blocks under each wing to prevent them from sagging.

As soon as the cement has dried, you are ready to glide your plane. Grasp the fuselage just under the wing between the thumb and forefinger and launch by a forward motion, starting directly above the shoulder and continuing straight forward. Care must be taken to start the plane off level, seeing that the wings are horizontal, also that the nose is not launched upward. A little practice will be all that you need to become an expert. Remember that the model can be made to loop the loop, glide straight or curve in a large circle back to the hands of the launcher, and many other stunts which are all controlled in the launching.

If your glider has a tendency to hunt — that is, to first dive into a long curve which ends in an upward climb, a stall, and then another dive, it is a sure sign that your wing is set too far forward. You can remedy this by adding weight. The easiest way to do this is to stick common pins in the nose until it glides to suit you. Small brads or thumb tacks also make good weights. Too much weight will cut your gliding angle down and reduce

the distance of your glide materially. When you get your glider balanced just right, take it to the nearest hill and let it soar. Remember to get a soaring flight it is necessary to have the wind blowing up the hill. Time your longest flights and let us know about them. Let's establish a new model glider record.



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